THE ROYAL CANADIAN INSTITUTE

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THE JOURNAL OF THE FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS,

PUBLISHED BY

THE INSTITUTE,

Under the Direction of the Committee on Publication.

Vol. CXVI.—Nos. 691—696.

THIRD SERIES.

VOL. LXXXVI.—JULY TO DECEMBER, 1883.

PHILADELPHIA:
Franklin Institute, No. 15 South Seventh Street

1883.

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JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVI. JULY, 1883. No. 1.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

NOTE RELATING TO "WATER-HAMMER" IN STEAM PIPES.

By PROF. ROBERT H. THURSTON.

[A paper read before the American Society of Mechanical Engineers, June, 1883.]

The writer has been called upon during the past winter, in the course of his professional work, to examine into the systems of steam heating in use on so large a scale in New York city, and elsewhere, and to report upon the condition and capabilities of one of those "plants" which have been put in operation. In the course of this investigation he was compelled to examine into the peculiar methods of injury to which long lines of steam pipe thus used are exposed.

The action familiarly known as "water-hammer" had been long known to him, as to every engineer who has had much to do with steam power, and its singular effects had been often observed and commented upon by him, as by others; but, in this case, these effects were developed on so large a scale, and were so serious oftentimes in their consequences as to impress upon him the desirability of examining into the matter more carefully than had yet been done. He has not been able to make a systematic and thorough investigation, such as he would have liked to make; but he has been able to collect some facts, a few of which will be here presented, that may at least have the effect of calling the attention of engineers more generally to this matter, and may lead to further study of the subject.

When a pipe is filled with steam, and then has introduced into it a quantity of cold water, or when a pipe, itself cold, and containing cold water, even in very small quantity, and without pressure, has steam turned into it, the first contact of the two fluids is accompanied by a sudden condensation, which causes a sharp blow to be struck, usually at the point of entrance; and sometimes a succession of such blows occurs, which are the heavier as the pipe is larger, and which may be startling, and even very dangerous.

It is not known, so far as the writer is aware, precisely how this action takes place in all cases, or what conditions are most favorable to the development of the tremendous pressures which are often produced. Perhaps the action is as follows:

The steam, at entrance, passes over, or comes in contact with the surface of the cold water standing in the pipe. Condensation occurs, at first very slowly, but presently more quickly, and then so rapidly that the surface of contact between the two fluids is broken, and condensation is completed with a suddenness that produces a vacuum. The water surrounding this vacuum is next projected violently from all sides into this vaccuous space, and crossing it, strikes upon the surface surrounding it. As water is nearly incompressible, the blow thus struck is like that of a solid body, and the intensity of the resulting pressure is the greater as the distance through which the portion of surface attacked can yield is less. In this manner enormous pressures are sometimes produced.

In some cases it seems certain that such pressures may be caused at points in the pipe far from either end, and from the point of entrance of the steam. For example, a pipe may lie in a nearly or quite horizontal line, and, if not fully drained, may contain a considerable quantity of water lying in the lower portion, while the steam may flow in above it. The passage of this steam along the surface of the water may cause some disturbance of the surface of the liquid, and this disturbance being gradually increased as the flow of steam becomes more rapid, may finally cause a break in the surface of the water, which disturbance may produce more rapid condensation and still further agitate the mass, until condensation occurs with such rapidity that a vacuum is formed at the point of greatest action. The next result is the rushing of steam from both directions towards this point, carrying with it, as it goes, masses of water which, coming from opposite directions with enormous velocity, meet at the intermediate spot at which the condensation has been most rapid, and being stopped by instant collision, produce a pressure which may only have as its limit the strength of the pipe.

Where pipes are not burst by this action, it is common to see them sprung and twisted out of line, torn from their connections, and, when a succession of shocks occur, as is often the case, the whole line writhes and jumps lengthwise to an extent that is sufficiently serious to cause well-grounded alarm.

The writer had an opportunity, in the course of his work on the case above alluded to, to obtain some probably approximate measures of the intensity of this action in long and heavy lines of pipe. Four lengths of 8-inch pipe had been split by this action, and the writer desired to ascertain whether they remained, in their injured condition, strong enough to bear the ordinary steam pressure of the line from which they were taken. This never rose above fifty or sixty pounds per square inch. They were therefore subjected, in a proving-machine, to gradually increased pressures until the already fractured parts were still farther injured, the repairs, or rather the patching having been carefully done in such a way that they were not strengthened by it. This was done by putting on soft patches along the line of the split and securing them by bolts which were set in the line of the split. The patches thus served as simple stop-valves, preventing the exit of the water through the break.

The following are the results of the tests:

Pipe No. 1.—This pipe was split, near one end, for a distance of 15 inches, along the line of the weld. When placed in the proving-machine, it bore the applied pressure until it attained an intensity of 400 pounds per square inch, when the split suddenly extended about ten inches; the pressure could no longer be kept up, and the test terminated.

The pipe was then taken to a pipe-cutting machine, and the injured part cut off. It was then again subjected to pressure. It bore a pressure of 1,100 pounds per square inch,—the highest that it was convenient or customary to apply to that size,—and was taken out sound.

Pipe No. 2.—This length was cracked for a distance of 15 inches along the line of weld, not far from the middle of its length. The crack had opened a little and the pipe was slightly bulged. This piece bore 300 pounds and then gave way, the fracture extending just enough to let off the pressure.

At the opposite end of the pipe was another split, 8 inches in length. The part just fractured was cut off, and the remaining portion was again subjected to the water pressure. This time it bore 1,050 pounds per square inch, when the crack was started and ran about 15 inches. It began leaking, and showed plainly the effect of the pressure at about 800 pounds.

This was an unusually interesting specimen, as the pipe had been bulged considerably by the water-hammer along the line of the 8-inch crack. The pressure afterward borne, therefore, seemed to the writer to be likely to be a fair measure of that produced originally by the water-hammer. Such bulging as was here seen never occurs at usual pressures. The new break did not follow the weld, but ran irregularly, and apparently indifferently, through weld or solid iron.

Pipe No. 3.—This length was split for a distance of 22 inches, the end of the break being about 3 feet from the end of the pipe. It sustained a pressure of 250 pounds. The sound part of the pipe was then tested up to 1,050 pounds without injury.

Pipe No. 4.—This piece was split, like the last, and to just about the same extent, was tested similarly, and gave way at 300 pounds per square inch.

All of this pipe was 8-inch pipe, $\frac{3}{8}$ inch thick, and made with the usual form of lap-welded joint. The welds were not always perfect, as is probably the fact with all such pipe; but this pipe, butt-welded, would have borne very much higher pressures than those to which it was subjected in ordinary work by the steam carried on the line. It cannot be asserted that these lengths of pipe did not split under pressures less than those to which they were afterward subjected by the writer, as it is very possible that the first blow may have found a weak part of the pipe, and the split may, in some cases, have extended to stronger portions. Nevertheless, the writer is inclined to believe that this was not the case in all instances, and is convinced that, in one case at least—that of the 8-inch crack, which was accompanied by a decided bulge in the pipe—the water pressures, at the test, were, at least approximately, equal to, and are very likely to have exceeded, those obtained at the later test. It seems to him very certain that we may consider it as proven that the pressures produced by "water-hammer" are often enormously in excess of those familiar to us in the use of steam, and that they have in many cases exceeded 1,000 pounds per square inch. It is, then, evident that it is not often safe to calculate upon meeting these tremendous stresses by weight and thickness of metal, but that the engineer must rely principally, if not solely, upon complete and certain drainage of the pipe at all times as the only means of safely handling steam in long pipes, such, especially, as are now coming into use in the heating of cities by steam led through the streets in underground mains.

The facts here presented have been, to the writer, something of a revelation, and have seemed to him to possess unusual interest and importance to the engineer using steam under such conditions as are here referred to. It is a fact which has long been well known, that these suddenly produced pressures are often very great. The writer has occasionally, for many years, known of serious and sometimes fatal accidents due to this cause; but that these stresses are often as great as is here indicated has probably been as little realized by engineers generally as by him.

Locusts in the Island of Cyprus.—The English government gives a penny and a half per pound for locust eggs. From July, 1881, to Feb. 1, 1882, 1329 tons of the eggs were brought to the English authorities and destroyed, each egg being much smaller than a pin's head.—*Rev. Scientif.*, Jan. 6, 1883. C.

Exploration of Greenland.—Nordenskiöld wishes to penetrate into the interior of Greenland, which, contrary to the general opinion, he thinks to be free from ice. This theory is based upon the fact that the *föhn* winds, or winds which are relatively dry and warm, must blow there. If such is the case, they cannot take into the interior of the country enough snow to feed a permanent glacier. He believes that vast regions covered with perpetual ice are a physical impossibility south of the 80th degree of North latitude. The illustrious voyager, with the energy and intrepidity which characterize him, does not hesitate to penetrate into the unknown deserts of the interior of Greenland, in order to test his theory. Among other studies, he proposes to continue those which he undertook in November last, upon the cosmic materials which the shooting stars bring to the globe. Those researches, in which he melted the snow collected at the surface of the ground, in order to examine its contents chemically, were not decisive; the residue consisted principally of feldspar and other terrestrial substances, without traces of metallic iron or nickel.—*Comptes Rendus*, March 5, 1883. C.

TABLE OF PISTON SPEEDS OF MARINE ENGINES.

By J. M. Whitham, Cadet-Engineer, U. S. N.

Name of Vessel.	Diameter of cylinders in inches.	Stroke of piston in feet.	IP (Total.)	Strokes of piston per minute.	Piston speed in feet per minute.	Remarks.
H. B. M. S. Inflexible...	70, 90, 90	4	8407	146	584	See King's "War Ships of the World."
" Neptune.....	118, 118	4½	8500	142	639	"
" Conqueror..	54, 70	3	4500	160	480	"
" Sultan........	117·9, 117·9	4½	7736	139	625·5	"
" Alexandra.	70, 90, 90	4	8600	134	536	"
" Téméraire ..	70, 114	3⅝	7700	148	567·6	"
" Shannon....	44, 85	4	3540	140	560	"
" Nelson........	60, 104	3½	6000	150	525	"
" Superb.......	116, 116	4	7430	134	536	"
" Dreadnought....	66, 90, 90	4½	8202	134·8	606·6	"
" Orion	65, 65	2½	4020	200	500	"
" Raleigh......	100, 100	4½	6157	147·8	665·1	"
" Boadicea....	73, 93, 93	4	5523	150	600	"
" Iris and Mercury..	41, 75	3	7714	194⅜	583·1	"
" Conquest ...	36, 64	2½	2300	200	500	"
" Garnet........	57, 90	2¾	2100	180	595	"
" Swift...........	38, 66	2	870	200	400	"
" Rover.........	72, 88, 88	4	4963·5	137	548	"
French, Admiral Dupené.........	61, 78⅜	39·4"	7397	154	505·6	"
Italian, Dandola.........	64, 120	4	....	160	640	"
" Duilio......	....	3¼	7710	168	546	"
" Christoforo Colombo.	....	37·5"	3782	172	537·5	"
German, Kaiser	114, 114	4	7890	154	616	"
I. R. S. Europe.............	42, 73	4¼	1800	130	552·5	"
" Asia..................	34, 56	3½	1050	132	462	"
" Africa....	34, 60	4½	1350	136	612	"
" Zablaca	34, 59	3	1470	184	554	"
" Novgorod.........	31, 45	2	499·6	200	400	See "Engineering," vol. xxi.
Austrian, Tagethoff....	125, 125	4¼	8000	140	595	See King's "War Ships of the World."
Dutch, Atjeh...............	72½, 72½	2⅛	2670	154	336·6	"

Name of Vessel.	Diameter of cylinders in inches.	Stroke of piston in feet.	HP Total.	Strokes of piston per minute.	Piston speed in feet per minute.	Remarks.
Chilian, Almirante......	46, 76	2½	2920	182	455	See King's "War Ships of the World."
" Huascar.........	54, 54	3	1650	156	468	"
U. S. S. Trenton............	58½, 78, 78	4	3100	120	480	"
" Quinnebaug....	42, 64	3½	1100	130	455	"
" Dispatch	33⅛, 34¼	2¾	403	129	356·6	See "Jour. of Franklin Institute," 1882.
" Miantonomah	32, 48 32, 48	3½	1600	130	455	See Edwards' "American Marine Engines."
" Essex and class	34, 54	3½	800	152	532	"
U. S. R. S. Rush............	24, 38	2¼	266·5	141·68	318·78	See "Engineering," vol. xxi.
" Gallatin......	34·1	2½	348	137·44	343·6	"
" Dexter.........	26	3	292	145·6	436·8	"
" Dallas..........	36	2½	234	126·8	317	"
U.S.F.C.S Fish Hawk	....	2¼	....	206	463·5	See Qualtrought's "Pocket Manual."
S. S. Hudson................	48, 48	6	....	138	828	See Edwards' "American Marine Engines."
" New Orleans........	48, 48	5	....	140	700	"
" Knickerbocker...	44, 44	6	....	140	840	"
" City of Pekin......	51, 88	4½	....	106	477	"
" " San Francisco......	51, 88	5	....	110	550	"
" Servia..................	72, 100, 100	6½	10350	106	689	See "Engineering," vol. xxxiii.
" Moor.....................	51, 90	5	4250	139·5	697·5	"
" Aberdeen.............	30, 42, 70	4½	2086	131	589·5	"
" Sterling Castle.....	63, 90, 90	5½	8509	133	731·5	"
" Ohio.........	57¼, 90⅛	4	1977·5	120	480	See "Engineering," vol. xxii.
" Britannic.............	48, 83	5	5000	110	550	See Goodeve's "The Steam Engine."
Yacht Leila...................	9, 16	1½	149·9	443	664·5	See "Report to Bureau of Steam Engineer'g"
" Gitana...............	13½, 15, 15	1·3	....	500	666·6	See "Engineering." vol. xxii.
An English tug............	14½, 25	1⅔	....	370	616·6	See "Engineering," vol. xxxiii.
Average piston speed for 56 vessels	....	....	....	....	544·066	
Locomotive "No. 5000"	....	2	....	700	1400	Built by the Baldwin Locomotive Co.
Italian torpedo boat....	....	1⅓	... .	960	1280	See "Engineering," vol. xxxiii
H. M. S. Polyphemus...	....	3¼	910	240	780	Designed speed. See same.
Small launch, named Bell Bird.....	8, 16	1	....	400	400	See "Engineering," vol. xxi.

U. S. Steamer Galena, Colonia, Uruguay, March 14, 1883.

LIQUEFACTION, VAPORIZATION, AND THE KINETIC THEORY OF SOLIDS AND LIQUIDS.*

By H. T. EDDY, PH.D., University of Cincinnati.

In a solid, in which the molecules are evidently held at nearly fixed mean distances by cohesive and elastic forces, there are two kinds of partially constrained freedom of motion possible for each molecule as a whole; first a motion of its centre in a small orbit of more or less irregular shape about a mean position; and second, a more or less irregular pendular motion of oscillation about a mean directional position. Both of these motions can be properly treated as vibratory motions, and the laws of force under which the motions occur, though somewhat unlike, as will appear during the following discussion, have a general resemblance.

When a solid is liquefied, it is evident that the molecules slide on each other with facility, which is equivalent to supposing that the molecules of the body have become perfectly free as to directional position; and this may be explained by supposing that the pendular oscillation has been changed into rotation.

In order to gain a clearer conception of how the mean potential and kinetic energies have been effected by such a change, let us consider the case of a simple pendulum, which may be taken to be a heavy particle suspended by a thin rigid rod. It is well known that for any small oscillation of this pendulum the mean potential and kinetic energies are equal, but for oscillations of more considerable amplitude this is far from being the case. In order to compare the mean potential and kinetic energies for larger amplitudes, it will be useful first to make comparison in case of a body of unit mass falling freely through a height s under the action of gravity, in which case we must, in order to obtain the mean kinetic energy compute the mean value of $\frac{1}{2}v^2 = gs$ during the fall. Let the mean value be denoted by a horizontal stroke

$$\therefore \ \tfrac{1}{2}\overline{v^2} = g\bar{s} = \frac{g\int s\,dt}{\int dt} \tag{1}$$

Since by the laws of falling bodies

$$s = \tfrac{1}{2}gt^2 \tag{2}$$

$$\therefore \ \tfrac{1}{2}\overline{v^2} = \tfrac{1}{6}g^2t^2. \tag{3}$$

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*Presented to the Section of Chemistry and Physics, O. Mech. Inst., April 26, 1883.

But the total energy potential and kinetic, which is evidently constant during the fall, is by (2),

$$gs = \tfrac{1}{2} g^2 t^2, \qquad (4)$$

and this is, therefore, also the mean value of the total energy. We obtain the mean value of the potential energy by taking the difference of the means.

$$\therefore\ g\,(s - \bar{s}) = \tfrac{1}{3} g^2 t^2. \qquad (5)$$

Hence by (3) the mean potential energy in a free fall is twice the mean kinetic energy. The same result holds in case of a body sliding down a smooth inclined plane. This result may then be applied to oscillations such as occur in the ideal case of a perfectly elastic particle which rebounds from a horizontal plane, whether vertically or obliquely, as is the case when it slides down one incline of a **V** and then ascends the other without friction. We are now in a position to see what is the relation between the potential and kinetic energies in case a smooth particle oscillates by sliding down one branch of a **U** and ascending the other. In the lower part of the curve the velocity is near its maximum value, and as this part of its path is more extended than before, the mean kinetic energy is greater in the **U** than in the **V**. Were the parts of the **U** which are nearly vertical put at a more considerable distance asunder, the mean kinetic energy could be increased at will by so doing. Now, it is known, in case the curve on which the particle oscillates is a cycloid, that the mean potential and kinetic energies are equal. Hence, in case it oscillates by sliding on any smooth curve, such as a semi-circle, whose vertical branches are not so far asunder as those of the cycloid which has a height equal to the radius of the circle, the mean kinetic is less than the mean potential energy. And it further appears that while for small oscillations the mean kinetic and potential energies are approximately equal, that as the amplitude of the oscillation increases, the mean kinetic energy is a smaller and smaller fraction of the total energy and of the mean potential energy. The same holds true in case the amplitude of the oscillation of the circular pendulum is pushed beyond 90° on each side of the mean. In fact, in case the kinetic energy at its lowest point is just sufficient to carry the particle to the highest point of the circle, the particle will rest there in unstable equilibrium, in which case the mean kinetic energy will vanish, since the time of oscillation is then infinite and the total energy will become potential and remain so. Thus we see that the mean kinetic energy of the pendulum may be any fraction of the total energy less than one-half, according to the amplitude of the oscillation.

But there is one other circumstance of importance in this kind of oscillation, which is, that although its total energy is constantly increased as the amplitude increases, it is far otherwise with the mean kinetic energy. This at first increases with the amplitude, though not so rapidly as the mean potential energy, but as the amplitude approaches 180° the time of oscillation is so greatly increased that the mean kinetic is actually decreased by an increase of amplitude. There is, therefore, a certain amplitude at which the mean kinetic energy is a maximum. What that amplitude may be it does not now concern us to determine; the only point necessary to consider is the one stated, that an increase of total energy and a consequent increase of amplitude will in no case increase the mean kinetic energy unless the amplitude of the oscillation be carried to more than 180°. As has been seen, a considerable increase of total energy will serve only to diminish the mean kinetic energy, but if sufficient total energy be supplied to the pendulum, the amplitude will exceed 180° and its motion will be changed from that of oscillation to revolution, and on sufficiently increasing the total energy the mean kinetic energy of revolution will be equal to the mean maximum kinetic energy of oscillation.

The application of the foregoing discussion to the oscillatory motion of the molecules of solid bodies is obvious. In case a molecule has one or more positions of directional equilibrium about which it oscillates, a sufficient increase of total energy (*i. e.*, heat) will bring its mean kinetic energy of oscillation to a maximum, and in order further to increase its mean rotary kinetic energy a large amount of potential energy (*i. e.*, latent heat) must be supplied to change the oscillations into rotations of the same mean kinetic energy (*i. e.*, to melt the body).

There is one other point to be noticed in this connection, which is, that according to this theory the specific heat of a solid will in general increase as its temperature rises towards the melting-point, which is in general accordance with experiment. It would be necessary, however, in order that this should universally be the case, to show that the mean energy of the particular molecular motion which is the physical cause of radiant heat, is proportional to the mean energy of the motion which we are now discussing. It is generally thought that such a relation exists, and it is certainly highly probable that the ratio between them does not change rapidly with the temperature.

The results which we have here obtained are not due to the fact that the force causing the oscillation considered was a special function of the amplitude, or of the distance of the particle from its mean position. The only vital point is that the oscillation shall be such that there shall be a maximum value of the mean kinetic energy. This remark has special application to the phenomenon of vaporization also, which we shall now consider. In vaporization the molecules are evidently removed to such considerable mean distances from each other that their paths are mostly free from mutual interference, while, before vaporization, the molecules are in no part of their paths free from mutual action and reaction.

In considering the forces which act along a line joining two molecules between which cohesive forces act, the phenomena of cohesion and of resistance to compression make it evident that the force with which a molecule is drawn towards its mean position, when their mutual distance is slightly greater than the mean, is one which at first increases with the displacement of the molecule from its mean position, but the displacement cannot be large without carrying the molecules beyond the range of their mutual cohesion. If, however, their mutual distance be decreased, the force tending to restore a molecule to its mean position increases with the displacement, and in such a manner that no force can bring them into actual contact.

The cohesive force actually existing between the molecules of a liquid is so masked by the phenomena necessarily accompanying liquidity that its true character has been largely overlooked. There is, however, no reason, as we think, to suppose that the forces acting to prevent decrease of volume in a fluid are different initially from those resisting dilatation, or at least that they differ more than the same forces do in a solid body.

In order that we may make clear the relations between potential, kinetic, and total energy in case of vibration under the action of molecular forces of this character, we shall in the first place discuss the subject of the relation between the law of force and the distribution of potential and kinetic energy somewhat in detail. The law of force in case of the pendulum already discussed is

$$y = \sin x \qquad (6)$$

in which y is proportional to the force acting to restore the particle to its mean position, and x is proportional to the displacement of the particle from its mean position at the origin, measured along its path.

In case of a force varying as the direct first power of the displacement, the corresponding equation is

$$y = x, \tag{7}$$

which is the equation of a line tangent to (6) at the origin, and hence, as before seen, for vibrations of small amplitude the two laws are approximately identical.

Now let a third law be assumed to be represented by an equation of a form such as

$$y = \tan x. \tag{8}$$

Since (7) is also tangent to (8) at the origin, for vibrations of small amplitude, the laws of force expressed by (7) and (8) will cause vibrations in which the distribution of kinetic and potential energy is approximately the same. If, however, sufficient energy is imparted to the vibrating particle so that the amplitude is not small, it is not difficult to see that the mean kinetic energy no longer remains equal to the mean potential energy, as it is when the law of force is expressed by (7), nor is the mean kinetic energy the less of the two, as when the law is expressed by (6), but instead it is now the greater of the two. This appears perhaps most clearly from the consideration that this case more nearly resembles, than do the preceding, that of an elastic particle rebounding between two fixed walls, in which case the mean potential energy vanishes, and the mean kinetic energy is the total energy. Hence, it appears that when (8) is the law of force the ratio of the mean kinetic energy to the total energy is greater than one-half, and increases with the amplitude of the vibration. This is true not only for the law of force expressed by (8), but for any law which is represented by a curve passing through the origin tangent to (7), and falling on the same side of (7) as (8) falls.

From similar considerations it appears that whenever the curve expressing the law of force passes through the origin and is tangent at that point to (7), and falls on the same side of (7) as does (6), the mean kinetic energy of vibration will be less than half the total energy. Since in (8) the force of restitution becomes infinite at both $+\frac{1}{2}\pi$ and $-\frac{1}{2}\pi$, the oscillation is confined within those limits.

Let us now further suppose a law of force which will give a curve not having a point of inflection at the origin as does (6) or (8), but nevertheless tangent to (7) at that point.

Such a law is given by the equation

$$y = e^{-\tan x} \sin x, \tag{9}$$

if we take only that part of it lying between $x = + \frac{1}{2}\pi$ and $x = - \frac{1}{2}\pi$. On the negative side of the origin the curve somewhat resembles (8), while on the positive side, after reaching a maximum value of y at a point a little beyond $x = \frac{1}{6}\pi$, the curve rapidly approaches the axis of x, and the force vanishes at $x = \frac{1}{2}\pi$. This is in effect a combination of the two previous cases, and corresponds evidently to the case of the molecules of a solid or fluid held at mean distances from each other which are fixed at a given temperature.

During one part of the vibration the mean kinetic energy is more than half the total energy, as has been just now shown, while during the other half the mean kinetic energy is less than half that amount. It will depend upon the precise relation between the two parts of the curve what the effect is on the whole. But it is perfectly evident that for large amplitudes the whole effect will be of the same character as if both parts were of the kind expressed by (6), and the mean kinetic energy is then less than half the total. But it is to be noticed that for certain amplitudes which are not too large the contrary effect is quite possible, and the mean kinetic energy will be less than half the total energy. This is the kinetic explanation of the fact first established by Rowland,* that the specific heat of water slightly decreases as the temperature rises, from 0° C to about 30° C. A similar phenomenon has been observed in case of mercury.

But the most important conclusion which flows from the fact that the mean kinetic energy decreases with the amplitude is that in this kind of vibration also, there is a maximum value of the mean kinetic energy which cannot be increased by increasing the displacement unless the molecules be carried beyond the range of their mutual attractions. This is what occurs in vaporization with the resulting change of volume, and a large increase of the potential energy without increase of the mean kinetic energy.

As was shown in connection with the discussion of the oscillation of the pendulum, the character of the oscillation is unchanged when the value of x in (6) lies between $+ \pi$ and $- \pi$, but entirely changes its character and becomes revolution if those limits are exceeded.

When the law of force is expressed by (7), the character of the

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*On the Mech. Equivalent of Heat, with subsidiary Researches on the Variation of the Mercurial from the Air Thermometer, and on the Variation of the Sp. Heat of Water. Reprinted from the *Proc. Am. Acad. Arts and Sciences*, Cambridge, 1880.

vibration is unchanged, however great the amplitude of the displacement; and similarly in case the law of force is that expressed by (8), the general character of the vibration cannot be changed, however large the total energy imparted to the vibrating particle, and in this case the amplitude of the vibration evidently cannot under any circumstances be increased beyond $\frac{1}{2}\pi$, but x must always lie between $+\frac{1}{2}\pi$ and $-\frac{1}{2}\pi$, so that as the amplitude approaches these limits, the motion resembles more and more that of an elastic particle rebounding between a pair of immovable parallel walls at a distance π from each other.

When, however, the law of force is that expressed by (9), the amplitude of the vibration cannot exceed $-\frac{1}{2}\pi$ in one direction under any circumstances, but in the other direction the amplitude cannot exceed $+\frac{1}{2}\pi$ without a change from vibration to free motion.

The phenomena to be represented show that the same general relation holds for any law of force of which the curve has the general characteristics of (9), such as, for example, that part at the right of the origin of the curve

$$y = ax^{-2} - bx^{-5} \tag{10}$$

in which y is the force and x the distance between the molecules. Such a curve as (10) must represent the facts of nature more accurately than the relation between them proposed by Maxwell, and expressed by the equation

$$y = -bx^{-5} \tag{11}$$

which was taken by him to express the force acting during an encounter. But the law of force during an encounter cannot be supposed to differ from that existing during any state of nearness of the molecules, so that (11) is to be regarded merely as an approximate expression for a law like that of (9) or (10), in which the part of the ordinate of the curve expressing the attraction of the molecules is neglected. It must be noticed that the origin in (10) and (11) is differently situated from that in (9), as will be seen upon sketching the curve. The line $x = -\frac{1}{2}\pi$ in (9) is that taken as the axis of y in (10) and (11).

Having now considered in general the nature of the change which occurs in the molecular motion during vaporization, a somewhat closer consideration will enable us to see the remarkable mechanical significance of the so-called critical temperature, as well as that of ebullition. In ordinary evaporation into the atmosphere, without ebullition only those molecules escape from the surface, whose kinetic energy is such as to enable them to overcome cohesion, and only so many can escape as will enable the vapor to fulfill approximately the law of Gay Lussac. The process by which the vapor tension in this case acquires its maximum value, is one whose velocity is regulated by the laws of gaseous diffusion, when the vapor tension is less than the atmospheric pressure. But when the temperature rises to such a degree that the mean kinetic energy of the molecules (which according to our theory may be the same in both liquid and vapor) is greater than that of the superincumbent atmosphere, the vapor no longer merely diffuses from the surface, but is able mechanically to push back the atmosphere, or other pressure, to which it is subjected, and ebullition takes place. Even in the case of ebullition, however, only part of the molecules are able to free themselves from the force of cohesion, namely, those molecules which happen to have a kinetic energy so far above the mean as to carry them out of the range of the force of cohesion, and enable them to push back the superincumbent pressure. If, however, the temperature be still further increased, a point must at last be reached, whatever be the volume and consequent pressure, such that the mean kinetic energy is greater than the maximum possible in the liquid state. The liquid must then become a gas without regard to volume or pressure. The temperature at which this occurs is the critical temperature for the liquid considered.

There are then three kinds of vaporization possible, evaporation, ebullition, and gasification.

There appears, however, to be only one kind of liquefaction, (melting) which is most nearly analogous to gasification, and without further reasoning it will appear that for those substances whose melting point is lowered by pressure there must be a critical temperature of melting above which the body will be liquid, whatever be the pressure, *i. e.* no pressure can lower the melting point beyond a certain amount dependent upon the constitution of the body.

The results of these views as to the mechanics of liquefaction and vaporization are in general accordance with the hypothesis of Clausius,* who supposes that the mean kinetic energy or "real specific heat" does not depend upon the state of aggregation of the body, and they are in exact accordance in this particular that the mean kinetic energy need not be changed by change of state from solid to liquid or from liquid to gas. But whether the translatory motion of the molecules is the direct physical cause of radiant heat is still an open question which we shall discuss more at length in another place, where we shall also take occasion to discuss the relation between the specific heats of a body in its different states of aggregation, solid, liquid and gaseous.

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* *Philos. Mag.* Series [4], 24, 1863.

There is, however, one point which may perhaps be well considered in this connection, and that is the explanation of the very large specific heat of liquids, compared with the same substances in the solid or gaseous state. This appears to be very probably due to the effects of the centrifugal force developed in the freely rotating molecules. The law of most probable distribution of rotary velocities shows that although the larger number of molecules are rotating with a velocity whose square is near the mean, yet all other velocities also exist, and among them very great ones.

Those rotary velocities which are sufficiently great will dissociate the atoms of the rotating molecules from each other, and the energy of rotation being expended against atomic forces will become potential and will not again become an available part of the kinetic energy until the atoms so separated meet others with which they can reassociate into molecules. A certain small per cent. of the total mass of the liquid must continually be thus dissociated in order that atoms may meet sufficiently frequently so that reassociation may be possible, and a uniform condition exist, in which as much reassociation happens as dissociation. This quantity must increase with the temperature, and the energy thus employed is apparently the reason of the high specific heat of liquids. In electrolysis these dissociated molecules are mechanically separated from the others, and to keep up the per cent. of dissociation a new supply is required for which energy must be supplied, just as it must be to preserve the temperature of a fluid from whose surface vapor is constantly being removed. A somewhat analogous phenomenon occurs in vaporization, but as it only can occur ordinarily at the surface, the analogy has been overlooked. A liquid gives off vapor at temperatures below boiling. According to the theory broached in this paper, only those molecules pass beyond the range of the cohesive forces whose kinetic energy is sufficiently above the mean to enable them overcome the cohesive force and have still remaining on the average an amount of kinetic energy equal to the mean.

But this can only occur at the surface, for inside the mass of the fluid such molecules are entangled and soon lose this superfluous energy in encounters with other molecules. We may perhaps put the comparison in a clearer light by supposing a liquid, in which no such dissociation occurs, such as mercury probably is, and let it be in connection with a large closed space which is filled with the vapor of the liquid at its maximum tension. Now raise the temperature of the fluid and wait until the vapor in the closed space has reached the tension corresponding to this temperature. The heat supplied is partly employed in increasing the kinetic energy, and partly in vaporizing a portion of the liquid, and is much larger in amount than would be required if there was no vaporization. In a quite analogous manner, the heat energy necessary to raise the temperature of water would probably be much less were there no dissociation accompanying the increase of temperature.

It appears from experiment that the specific heat of mercury is nearly the same in its solid and liquid states as it should be in case its molecules are monatomic in both states. It would be of great interest to know whether the specific heat of mercury gas has also the same value. It is noticeable that the latent heat of liquifaction of mercury is extremely small, which would lead to the hypothesis that the atoms of mercury are very nearly round and smooth, and that the rotary energy of a molecule of mercury but a very small fraction of its total kinetic energy.

Cadmium, which is monatomic as a gas, would also furnish an interesting test of the theory, for it is not likely that the molecule of a substance greatly changes its character by change of state. Dissociation of the atoms of a molecule is evidently due to the motion of atoms away from each other. It is yet a question as to whether such oscillations can be caused in the atoms of a molecule as to absorb an appreciable amount of energy, or of such intensity that they can be caused to rotate. If such rotations are ever caused within the molecule itself, they probably occur at temperatures far above vaporization.

The conclusions to be drawn from the specific heats of elementary substances whose molecules consist of but two like atoms are in general confirmatory of the theory proposed in this paper, for the amount of rotary energy for such substances should be a less fraction of the total energy than in bodies consisting of a larger number of atoms, and the per cent. of dissociation should also be less. Now, in fact, for such bodies the specific heat in the liquid state does not, in general, greatly exceed that in the solid.

ABSTRACT OF PAPER ON THE COMPARISON OF INDICATOR RIGS.

By Robert Grimshaw.

[Read before the Franklin Institute, May 18, 1883.]

Correct instruments may be applied and used in wrong ways, and give incorrect results.

The steam engine indicator is frequently so applied and used; the devices employed to reduce the motion of the crosshead often causing great errors in the diagram.

Among the methods we may consider

(1) Cord attachment from a pin in the end of the shaft or side of crank, direct to the paper barrel.

(2) Cord from a swinging lever slotted to receive a pin in the crosshead.

(3) Cord from a swinging lever connected with the crosshead by a vibrating link.

(4) Cord from a swinging lever attached to the crosshead; the pivot of this lever vibrating at the end of a swinging link.

(5) The reducing wheel.

(6) Pantograph.

(7) "Lazy Tongs."

In devices 2 and 3, which are the most commonly used, the cord may be either

(*a*) Attached directly to the lever.

(*b*) Wrapped around a circular arc or sector centered in the pivot of the pendulum.

No. 1 is irrevocably tainted with the angularity of the connecting-rod, compounded with that of the cord. It always gives less than ¼ the diagram-length, for the first quarter of the out-stroke of the piston; and gives longer cards on an indicator at the back end than at the crank end. The shorter the connecting-rod and cord, for a given stroke, the greater the errors.

(2) The slotted lever gives absolutely correct results when at mid-stroke, it is perpendicular to the crosshead path, and when,

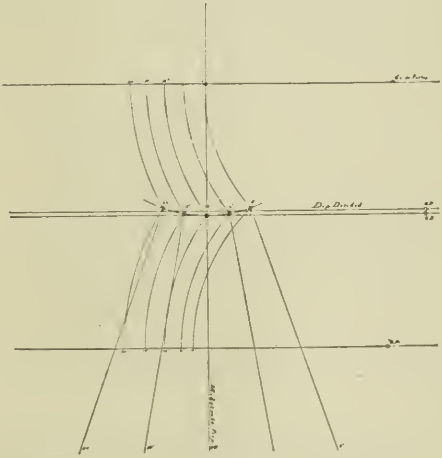
(*a*) The cord gets its motion from a pin which is driven by a radial slot centered in the pivot of the lever, and perpendicular to the cord at mid stroke.

(*b*) With long cord attached directly to the lever the results are practically correct, provided that the "dip" of the cord is divided, and the cord is led off so that at mid-stroke it makes a right angle with the radial line from its attachment to the pivot.

(*c*) With a long cord wrapped around a circular arc, centered in the pivot, the results are practically correct, no matter how the cord is led off.

This theoretical, but practically immeasurable error, gives equal cord lengths for both halves of the stroke, but the end quarters give somewhat longer card lengths than the central quarters. The error decreases with the total angles of lever and cord swing.

Fig. 1.



Motion of Usual Pendulum and Link.

(3) The lever with fixed pivot, and linked to the crosshead, gives quite good results when properly applied, although not so accurate as a double-slotted lever of the same length.

At mid-stroke it should be vertical, and the link sufficiently below the crosshead attachment to divide the dip.

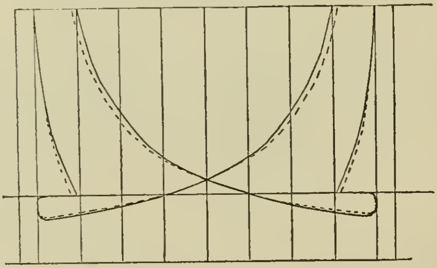
Remarks *b* and *c* concerning the cord attachment to the slotted lever apply to this rig. As in the latter rig also, the longer the lever, and the cord between lever and guide pulley, the more accurate the results.

Fig. 1 is reduced from a carefully made plotting, full size, of the motion of a rig with levers 36 and 24″ long. The vertical line represents the position of the pendulum at mid-stroke. The dip of the link was divided at this position. Four different cord angles gave as many varying results. When the angle of cord vibration was divided and the guide pulley placed at the point *GP* on the second horizontal line parallel to the crosshead path, the error in a 4″ card was hardly measurable. Circular arcs swept from the upper point *GP*, from the points indicating successive positions of the point of cord attachment, show that with this position of guide pulley the first quarter of the forward piston stroke gives more, and the last quarter less, than a quarter of the card length, this being reversed on the back stroke.

Carrying the guide pulley below the line of divided cord vibration, the errors of card length are exactly the opposite of those made with the guide pulley above the line of divided cord vibration.

Fig. 2 shows in dotted lines the result of putting the guide pulley even so little below the line of divided cord vibration as the bottom of the arc described by the cord attachment. The correct cards for the plotted amount of clearance and points of cut-off and compression are in full lines.

Fig. 2.



False Diagrams taken by Usual Pendulum and Link.

(4) The pendulum with swinging centre is probably the most erroneous used or proposed. Fortunately it is not a usual rig. It does not permit of the use of a circular sector for cord attachment, nor can the cord be attached, as in where the pendulum pivot is stationary, anywhere but in the line of centers of the long lever; thus losing one of the main advantages of fixed centre levers, the dispensing with a guide pulley.

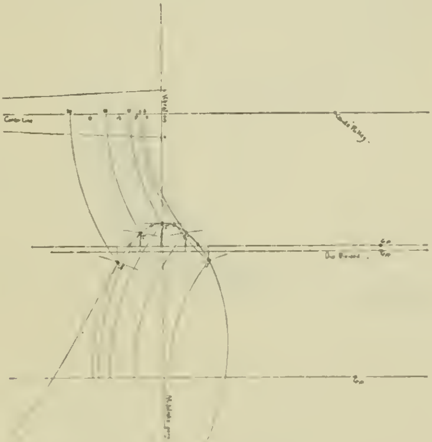
The point of cord attachment describes a mixed curve which is neither regular nor symmetrical, one limb being variably convex, and part of the other being decreasingly convex and then increasingly concave.

With the lever plumb at mid-stroke, the "dip," or versed sine of the swing of both levers divided at mid-stroke, and the cord running off parallel to the crosshead path, the results, while not so correct as those from the other lever rigs, and not accurate enough to set valves by, will do to give a general idea of engine performance and an approximation as to horse-power.

The greater the angular vibration of pendulum, link and cord, and the greater the angle made by the cord with the path of the crosshead, particularly where the cord makes an acute angle with the radius between cord attachment and swinging centre, the greater the error.

This tendency to error is so great, that some cord angles likely to be chosen by any one not thoroughly conversant with the errors of this rig, actually give a negative movement to the paper drum, during the first portions of the outstroke; so that for an engine with a lazy steam valve the admission line would appear as compression to initial pressure, and with cut-off at $\frac{1}{16}$ stroke the diagram would commence with the expansion curve and have two vacuum loops so large as to prove the engine to be driven by the main belt and pumping into the boiler.

Fig. 3.

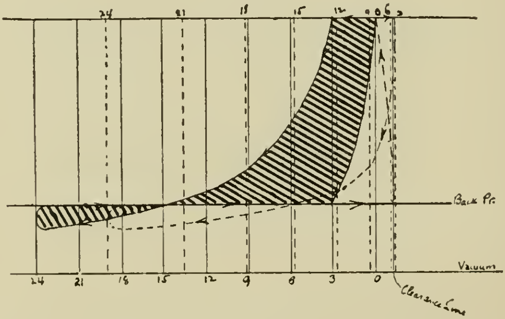


Motion of Lever with Vibrating Pivot.

Fig. 3 is a photo reduction from a plotting made with scrupulous care, with a 36″ pendulum swinging on a 24″ link, the "dip" or versine of the latter being divided by the vertical line, which represents position at mid-stroke. The curved trace was made by inserting a pencil point in the hole for cord attachment; the line being the "raised curve" referred to in a previous paragraph. The nine small circles on this curve show the successive positions of the cord attachment at equidistant portions of the piston stroke. With the angle of cord vibration divided, the error on a 4″ card is measurable, but not serious for rough calculations of horse-power, though sufficient to throw the cards out for plotting true theoretical expansion curves. The slightest variation from this height of guide pulley produces an error so great as to vitiate any cards with early cut off, even for horse-power calculation.

With the guide pulley much above the line of divided card vibration, as shown in the diagram, there is produced the astounding result referred to in a preceding paragraph :—During the first eighth of a forward stroke the cord slacks, and is not again tightened until the end of the third eighth of the stroke. The positions of the point of cord attachment at successive eighths of the forward stroke are shown in Fig. 3; while in Fig. 4, the dotted lines show the false cord which would be produced with 60 lbs. absolute initial pressure, and cut off at $\frac{1}{8}$ stroke (clearance and compression being as shown in the correct theoretical diagram hatched in full lines). The numbers 0, 3, 6, etc., on the lower line indicate correctly successive piston positions; the same numbers on the upper line showing where the piston would be represented to be, by the rig shown.

Fig. 4.



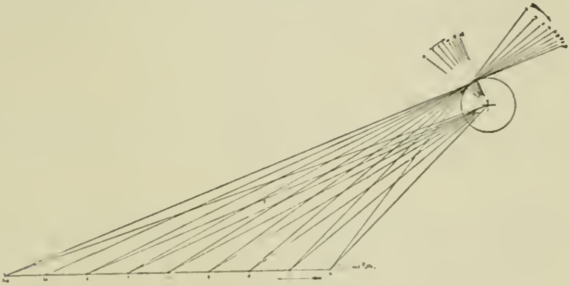
False Diagram by Lever with Swinging Pivot.

(5) The reducing wheel gives absolutely correct results when properly applied, which is seldom the case. The cord should be led from an offset from the crosshead, so that it will, at all piston positions, be

absolutely parallel to the piston rod. When it makes an angle with the rod, it gives a shorter card than due to the stroke, but not only that, the card for any given fraction of the out-stroke is shorter than that for the succeeding one.

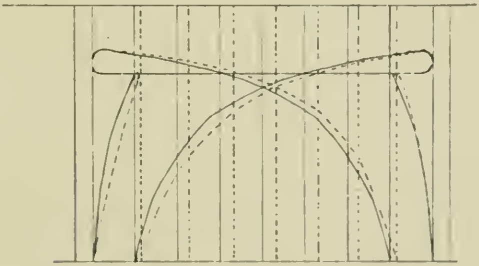
These errors being due to the decreasing angle of the cord as the piston advances, it follows that if the indicator is screwed into first one end of the cylinder and then the other, the diagram from the crank end will be not only shorter than that from the back, but more distorted; and that the further the wheel is from the central line of the engine, and the nearer the crosshead attachment to that same axis, the greater the error.

Fig. 5.



Motion with Wrongly Applied Reducing Wheel.

Fig. 6.



False Diagrams taken by Reducing Wheel.

False cards by this rig always show the cut-off too early and horsepower too low on the out-stroke, and the reverse on the return.

In Fig. 5 there are plotted eight equal successive portions of a 24″ forward piston stroke, and a 4″ reducing wheel wrongly applied. The angles made by the tangents representing the successive positions of cord, are greatest for the earlier equal portions of the outward stroke;

so that instead of correct diagrams like the full lines in Fig. 6, three are taken such as are shown by the dotted lines; the right hand card being from the back end.

(6) The pantograph can be made to give perfect cards, the only danger being in oblique cord connections.

(7) The same remarks apply to the lazy tongs; but in this there appear two special sources of error: lost motion in a multiplicity of joints, and springing of the frame at high speeds, prolonging the card at the two ends, hence making cut-off appear too early and horse-power too low.

In all cases, the cord should be light and non-stretchable. Braided cord is best, if cord is to be used; piano wire is better, and absolutely prevents the objectionable use of a guide pulley.

[Since preparing this paper, Mr. B. F. Teal has submitted a model of a method of reducing the crosshead motion by differential pulleys carried on the crosshead, and giving the paper-drum positive motion on each stroke.]

The results of my investigations and tests are, that for accurate results at high speeds, the slotted lever is by far the best rig, from its simplicity, cheapness, ease of attachment while engine is running, lack of spring, direct cord connection, and adaptability to various lengths of stroke and position of indicator.

[Before this abstract was in type, the appearance of a lengthy mathematical discussion of this question in a well-known magazine, by a gentleman who commenced a discussion of the paper itself at the meeting at which it was presented, renders it necessary for the writer to add to the abstract a memorandum of the manner in which the tests and measurements were made.

Hard wood pendulums and links were made, with the pivot centres accurately laid down, drilled squarely with a $\frac{1}{16}$th twist drill, and their distances carefully measured. Scribe lines were drawn and carefully drilled in the same manner to mark successive eighths of 24″ piston strokes. With a tested T square, the mid-stroke positions of the levers were laid down previous to drilling the centres for piston position holes. The levers were then accurately centred, and the point of cord attachment drilled for a metal-marking point which should not only make a trace of the entire motion-curve of the point of cord attachment, but would prick the positions of that point at each piston position. The distances from guide pulleys were transferred by stiff trammels, and the card lengths measured to hundredths of an inch as well as graphically recorded.

In addition to the graphical tests and proofs made by the levers themselves, full-sized diagrams were made with a hard pencil, and these were measured to check the graphical records.

In still further corroboration, an indicator was clamped to the drawing-board in various positions, and the successive eighths of piston stroke recorded on the usual paper card by direct cord attachment to the levers.

The levers, thus connected to the indicator, were shown at the Institute meeting, and cards from the "swinging-pivot" lever were taken by the author, and handed out at the meeting, corroborating those portions of the paper which referred to that rig. After the meeting, the writer offered the indicator to the member who upheld that rig, if he would either take a correct card with that rig, or disprove the methods and measurements there offered. The author still owns the indicator.

The writer's measurements, particularly those of the swinging-pivot lever rig, were checked by skilled engineers and draftsmen in various parts of the country, and the levers and board are on deposit at the Franklin Institute, for the convenience of those who may wish to test for themselves.

ERRATA.

Page 22, third line from top, for "raised curve" read "reversed curve;" on fourteenth line from top, for "a" read "the;" on tenth line from bottom, for "cord" read "card."

Page 24, first line, for "three" read "there."

Page 25, formula should read: "Given, $a = b$; then, $a^2 - b^2 = ab - b^2$; $(a+b)(a-b) = b(a-b)$; $a+b = b$; $2 = 1$."]

[illegible] was used for four days without disturbing the mounting and was employed every evening to produce electric light.—*Comptes Rendus.* C.

Magnetism of Rotation.—Tresca has reported to the French Academy some experiments by Selim Lemström upon the causes of terrestrial magnetism. He used a paper tube with two concentric walls, rotating rapidly around a cylinder of soft iron, and his results confirmed the theories of Edlund and Chase, which explain magnetic effects by æthereal movements. The experiments were substantially the same as those which were performed by Chase in 1864 and 1865, and reported in the ninth and tenth volumes of the Proceedings of the American Philosophical Society.—*Comptes Rendus.* C.

INVESTIGATION OF THE CIRCUMSTANCES AFFECTING THE POTABILITY OF THE SCHUYLKILL WATER SUPPLY IN THE MONTH OF JANUARY, 1883.

EXECUTED UNDER THE AUTHORITY OF THE BOARD OF EXPERTS AND THE CHIEF ENGINEER OF THE WATER DEPARTMENT OF PHILADELPHIA, BY PROF. ALBERT R. LEEDS, PH. D.

LABORATORY OF CHEMISTRY.

Stevens Institute of Technology,
Hoboken, N. J., February 20, 1883.

To MESSRS. FREDERICK GRAFF, J. VAUGHN MERRICK, Members of the Board of Experts, and COLONEL WILLIAM LUDLOW, Chief Engineer of the Philadelphia Water Department.

GENTLEMEN:—I transmit herewith my Report containing the results of an investigation into the causes affecting the potability of the Schuylkill River water, during the month of January of the present year. It should be premised that this investigation largely excluded those causes which could be determined by direct observation, such as impurities carried into the river by surface and subsoil drainage, by sewers, by the refuse of factories, from cesspools, from the spent liquors of gas works, from the irruption of animal matters derived from slaughter houses, etc., etc., and was principally confined to the study of those causes which might be discoverable by physical and chemical examination of the waters themselves.

Though this restriction, which was due to the limited scope of my official instructions is much to be regretted, yet it necessitated a more thorough search within the narrow field of laboratory analysis and experiment open to me. It is also less to be regretted for the following reasons:

The *fact* of the principal source of the Philadelphia water supply, the Schuylkill, being at the present time a sewer and factory-polluted stream, was conceded. It was also well established that the actual potability of the water at any particular season, is determined:

1st. By the ratio then existing between the volume of flow and the volume and character of polluting materials, a small amount of contamination when the volume of water is at a minimum, possibly damaging the potability far more than the maximum amount of pollution existent along the banks of the Schuylkill, when its flow is also at a maximum.

2d. By the relative energy of the agencies (mostly artificial) at work to contaminate, and the agencies (almost, if not entirely natural) operating to purify the stream. If these natural agencies are in full sway, they may dispose of a large amount of impurities and bring the water back into such a condition as neither to affect the sense of smell or taste, or exert a detrimental effect upon health.

There are ample grounds for believing that, up to the present time at least, this balance of opposing forces has usually inclined to the favorable side in the case of the Schuylkill water, and that therefore it has been entitled to be ranked as a wholesome water supply. Similar conclusions were arrived at by Professors Booth and Garrett, and by Dr. Charles M. Cresson, in their elaborate reports appended to the "Report of the Commission of Engineers on the Water Supply of Philadelphia, 1875." On the other hand, if their operation is least active on account of an unpropitious season of the year, or stagnant conditions of the water, or possibly of a covering of ice, they may be unable to dispose of a small quantity of polluting material, and at such a time the water supply may become most offensive.

I shall not anticipate, however, results obtained and conclusions based thereon, but shall present in detail the work actually performed. This may be most concisely done under the five following heads:

1st. Collection of the samples.

2d. Methods of analysis.

3d. Interpretation of the data obtained by analysis and experiment.

4th. Light thrown by the results upon the origin of the January taste and smell.

5th. Questions relating to the deterioration of the water supply.

1. COLLECTION OF THE SAMPLES.

During the latter part of the period when the water was in its most nauseous conditions, by the authority of the Water Commission and Chief Engineer, Dr. Wm. H. McFadden, the following samples were collected and forwarded to me for analysis.

I. Schuylkill river at Pottstown, January 10, 1883. (Laboratory No. 226.)

II. Schuylkill river at Roxborough, January 10, 1883. (Broken in transportation.)

III. Schuylkill river at Schuylkill Works, January 9, 1883. (Broken in transportation.)

IV. Schuylkill river at Norristown Works, January 10, 1883. (Laboratory No. 227.)

V. Schuylkill river at Fairmount Works, January 9, 1883. (Laboratory No. 228.)

VI. Schuylkill river at Belmont Works, January 9, 1883. (Broken in transportation.)

VII. Schuylkill river at Fairmount Works, January 13, 1883. (Laboratory No. 229.)

Subsequently, being desirous that my investigation should extend beyond the determination of the mere fact of contamination, and should be directed to the discovery, if possible, of the origin of the bad taste and smell on this particular occasion, the Chief Engineer desired me to visit the Schuylkill river in person, and collect such additional samples as would be of value.

In accordance with these instructions, January 19 and 20 were spent upon the ice, then covering the river, in company with Assistant Engineer, C. G. Darrach, whose aid was of the greatest service in carrying out the proposed line of inquiry.

In the first place it was deemed important to ascertain whether there was a difference of temperature between the water at the bottom of the river and at its surface, or rather immediately under the ice. If such proved to be the case, there would be a corresponding difference of density, and possibly a difference in composition. To make these determinations, a bottle, containing a thermometer, was properly weighted so that it might sink in a vertical position until the bottom of the bottle came to within about three inches from the bottom of the stream. The stopper was then pulled out, and after filling, the bottle was quickly pulled to the surface and the temperature noted. The temperature of the surface samples was also observed whilst the thermometer was immersed in the bottle, this precaution being taken to exclude errors arising from atmospheric influence. In this manner the following six samples were obtained.

SAMPLES COLLECTED IN PERSON JANUARY 19 AND 20.

No. 230 Surface water, Fairmount Basin, January 19.
No. 237 Bottom water, Fairmount Basin, January 19.
No. 233 Surface water, Spring Garden Basin, January 19.

No. 232 Bottom water, Spring Garden Basin, January 19.
No. 235 Surface water, Roxborough Basin, January 20.
No. 234 Bottom water, Roxborough Basin, January 20.

The observed temperatures were as stated; the specific gravities at 15° were subsequently determined with great care in the laboratory, and are likewise given.

No.	Temperature Air.	Temperature Water.	Specific Gravity at 59° F.
230	34°	33°·2	1·001468
231	34°	33°·8	1·001477
233	34°	33°·4	1·001471
232	34°	33°·8	1·001471
235	36°	33°·	Undetermined.
234	36°	33°·4	"

Two points deserve comment with regard to these determinations:

1. The average density of the Schuylkill water at the time when the samples were taken, when reduced to the mean temperature of 59° F., was very approximately 1·00147, and inasmuch as the volume of pure water, according to Kopp, diminishes from 0·999966 to 0·999947, when its temperature is raised from 33·4° F., to 33°·8, the density of the bottom sample, No. 232, at the time it was collected, was 1·0022202, while that of the surface sample, No. 233, was 1·0022081. There is therefore in winter, when the river is covered with ice, a current of colder water flowing immediately beneath the ice, and another current, of warmer water, but of greater density and probably flowing much more slowly, at the bottom of the stream.

2. The temperature of the water in the Schuylkill in midwinter, and when the river had been for some time entirely covered with ice, was about one Fahrenheit degree above freezing point at the surface, and about 1·4 above freezing point at the bottom, or four-tenths of a degree warmer.

2. METHODS OF ANALYSIS.

Inasmuch as a knowledge of the methods employed is essential to the proper understanding and interpretation of the analytical results, it is necessary to state briefly what these methods were.

FREE AND ALBUMINOID AMMONIA.

The method of Wanklyn, Chapman, and Smith, performed in accordance with certain modifications described at length in the *Zeitschrift für Analytische Chemie*, xvii, p. 276, was made use of. These modifications are, in brief, the employment of a Color Comparator, which admits of the comparison of the test with the standard under conditions most favorable to accurate comparison. Secondly, the substitution for the various standard solutions, which have to be freshly prepared for each analysis, of a standard wedge graduated once for all with extreme care. This wedge can be used for months without its scale undergoing alteration, and its employment insures uniformity between the results of analyses performed at different times, and greatly shortens the length of time required for the performance of long series of analyses.

OXYGEN REQUIRED TO OXIDIZE THE ORGANIC MATTERS, OR "REQUIRED OXYGEN."

This was determined by potassium permanganate in acidified solution, the samples being plunged for exactly 10 minutes in water at 98°. All of the samples were treated in precisely the same manner, and a correction was applied to each result, amounting to the value of the alteration of the reagent, when tested upon distilled water under identical conditions. After many unsuccessful attempts to obtain concordant results by this method, I had recourse to a new one, devised during the course of this investigation, and which is founded upon the reduction of silver salts in solution by organic matter in sun-light. This is not the proper place to give the details of the new "Actinic Method," nor the experiments which led me to abandon the potassium permanganate test, the publication of these details being necessarily left to the chemical journals. I have given, in the accompanying table, the results obtained by the use of potassium permanganate for samples 230 to 235, and by the Actinic Method for same samples. It will be noted that the figures obtained by the Actinic are higher than those obtained by the Permanganate process. My own conclusions in the present investigation are based on the results obtained by the former method.

REQUIRED OXYGEN.

No.	PERMANGANATE PROCESS.	ACTINIC PROCESS.
230	0·18 parts per 100,000.	0·218 parts per 100,000.
231	0·19 " "	0·244 " "
233	0·18 " "	0·299 " "
232	0·18 " "	0·283 " "
235	0·16 " "	0·206 " "
234	0·16 " "	0·231 " "

Nitrites.—The nitrites were determined by means of hydrochlorate of naphthylamine and sulphanilic acid, according to the reaction discovered by Griess, and which is so sensitive that it permits of the easy recognition of one part of nitrous acid when diffused through a thousand million parts of water. They were calculated as nitrous acid (HNO^2).

Nitrates.—These were determined upon a deciliter of the water, after evaporation to dryness, subsequent heating in presence of lime, reduction in the cold by a copper zinc couple, and complete distillation of the formed ammonia. They were calculated as nitric acid (HNO^3).

Total Solids.—These results express the weights of the residues obtained by the evaporation of a deciliter and drying to constant weight at 100°C.

Dissolved Oxygen.—The number of cubic centimeters of oxygen dissolved in a liter of water was determined by Mohr's method, which is based upon the relative amounts of oxidation of protoxide of iron to the form of peroxide, effected by the various volumes of oxygen held in solution.

The results obtained by this process are closely concordant among themselves, and whilst they do not possess the same degree of absolute accuracy as those obtainable by the laborious eudiometric methods of Bunsen, yet, Mohr's method has the great advantage that it admits of the determinations being made upon a number of samples before such an interval has elapsed, that the constitution of the water and dissolved gases have possibly undergone considerable change.

Acidity and Alkalinity.—To determine whether the water possessed an acid or alkaline reaction, and the actual amount of the acidity or alkalinity as the case might be, centinormal standard solutions were employed with alizarine and phenolphthalein as indicators, according to the method given in the *Jour. Amer. Chem. Soc.*, ii, p. 71.

Sanitary Analysis of the Philadelphia (Schuylkill River) Water Supply, 1883, *by Prof. Albert R. Leeds, Ph.D.*

	No. 226—Pottstown, January 10.	No. 227—Norristown, January 10.	No. 228—Fairmount forebay, January 9.	No. 229—Fairmount forebay, January 13.	No. 230—Fairmount basin, at surface, January 19.	No. 231—Fairmount basin, at bottom, January 19.	No. 233—Spring Garden basin, at surface, January 19.	No. 232—Spring Garden basin, at bottom, January 19.	No. 235—Roxborough basin, at surface, January 20.	No. 234—Roxborough basin, at bottom, January 20.
Free ammonia.										
Parts per 100,000	0·009	1·0125	0·0195	0·02075	0·0165	0·01575	0·013	0·01775	0·017	0·01325
Grains per gallon	0·0052	0·0073	0·0113	0·0111	0·0096	0·0091	0·0078	0·0103	0·0099	0·0077
Albuminoid ammonia.										
Parts per 100,000	0·0145	0·0125	0·02375	0·01425	0·01275	0·01425	0·01175	0·01375	0·015	0·01425
Grains per gallon	0·0084	0·0075	0·0138	0·0083	0·0074	0·0083	0·0068	0·0082	0·0087	0·0083
Ratio of free										
To albuminoid ammonia	1 to 1·6	1 to 1	1 to 1·22	1·46 to 1	1·3 to 1	1·1 to 1	1·1 to 1	1·3 to 1	1·3 to 1	1 to 1·08
Oxygen required to oxidize.										
Parts per 100,000	0·20	0·13	0·37	0·30	0·18	0·19	0·18	0·18	0·16	0·16
Grains per gallon	0·116	0·105	0·21	0·175	0·105	0·111	0·105	0·105	0·093	0·093
Nitrites.										
Parts per 100,000	0·005	0·0066	0·005	0·0066	0·0083	0·0083	0·01	0·0083	0·005	0·005
Grains per gallon	0·0029	0·0038	0·0029	0·0038	0·0048	0·0048	0·0058	0·0048	0·0029	0·0029
Nitrates.										
Parts per 100,000	0·323	0·355	0·369	0·355	0·361	0·36	0·374	0·361	0·439	0·43
Grains per gallon	0·188	0·207	0·215	0·207	0·212	0·210	0·218	0·212	0·256	0·251
Chlorine.										
Parts per 100,000	0·45	0·525	0·65	0·70	0·65	0·65	0·65	0·60	0·45	0·475
Grains per gallon	0·262	0·306	0·379	0·408	0·379	0·379	0·379	0·35	0·262	0·277
Total solids.										
Parts per 100,000	18·00	18·00	18·50	18·50	18·50	18·50	19·00	18·50	18·50	18·50
Grains per gallon	10·49	10·49	10·79	10·79	10·79	10·79	11·08	10·79	10·79	10·79
Dissolved oxygen										
In one liter	....	....	....	....	4·41 cubic centimeters.	5·13 cubic centimeters.	4·31 cubic centimeters.	5·18 cubic centimeters.	5·32 cubic centimeters.	5·61 cubic centimeters.
Acidity.										
Calculated as sulphuric acid	0·00018 parts per 100,000	0·00002 parts per 100,000	0·00007 parts per 100,000							
Alkalinity.										
In terms of sodium hydrate	....	....	....	*0·00003 parts per 100,000						

* The samples collected January 19 and 20, had a neutral reaction.

3. INTERPRETATION OF DATA OBTAINED BY ANALYSIS AND EXPERIMENT.

During the entire course of this investigation, one great object was left prominently in mind, and the character of the analytical operations performed was governed entirely by considerations as to what manner of analyses and experiments would throw most light upon the the question: Why at a certain particular period did the water in the Schuylkill river suddenly become unpalatable? My present object is to discuss seriatim the various classes of analytical results obtained, and to endeavor to present judicially and fairly the answers which these various classes of data severally give to the above questions.

1. THE FREE AND ALBUMINOID AMMONIA.

The information supplied by these determinations, bears especially upon the three following points:

1. The amount of Free Ammonia, which is the measure principally of that portion of the decomposable nitrogenous matter that has already undergone decomposition, is very much greater in all the samples (0·009 parts in 100,000 to 0·02075 parts) than in the water of the Schuylkill river, June 24th, 1881 (0·001 part).

2. The Albuminoid Ammonia, which is the measure of that portion of the nitrogenous matter as yet undecomposed, but capable of undergoing decomposition, is large (0·01175 parts to 0·02375 parts). At the same time it is not so great in any of the samples, with the exception of the one taken from the Fairmount Forebay, January 9th, as it was in the Schuylkill water, June 24th, 1881. Yet this last, as compared with the water supplies of the principal cities in the United States at that date, was ranked as third in order of purity. In other words, the absolute amount of decomposable organic matter in the Schuylkill water, at the time when it acquired its nauseous taste and smell, was not so great as at a season when it was palatable. This statement is borne out by the other analytical data, and I think it can be justly inferred that the unpalatability was due not to an unusually large amount of the polluting materials, which exist at all times to a greater or less extent in the waters of the Schuylkill, but to some peculiarity either in their character or in the nature of their decomposition.

3. There is no evidence, as will be seen farther on, of any peculi-

arity in the organic matter itself, which would account for the taste and smell. There is, however, a very striking peculiarity in the nature of its decomposition. By reference to the table of analyses, it will be seen that the *Free Ammonia exceeds the Albuminoid in almost every sample analysed.* That this is anomalous, will be seen by comparing these analyses with those of the various city waters in the United States, June and July, 1881.*

	Free Ammonia. Parts per 100,000,	Albuminoid Ammonia. Parts per 100,000.	Ratio.
Philadelphia	0.001	0.018	1 : 18
Boston	0.013	0.061	1 : 5
New York	0.0027	0.027	1 : 10
Brooklyn	0.00075	0.00825	1 : 9

This point is still more strikingly brought out by the series of analyses made upon 34 samples of water collected at various points along the Passaic river, from a point above the interruption of the sewage and factory refuse of Paterson, to a point below the lowest sewers of Newark, a distance of 20 miles.

These samples were all collected upon the same day, September 6th, 1881, when owing to three months of drought no water had gone over the dams for many weeks, and the water had become very offensive. But in the eleven samples in which the free ammonia exceeded the albuminoid ammonia, this excess was directly connected with the sewage of manufacturing towns and with the refuse of cotton, paper and woolen mills, and of dye-houses, thrown into the stream at points in proximity to those whence these samples were collected. Above these factories, and at a point 16 miles below them, near the intake of the Jersey City Pumping Station, there was little or no free ammonia in the stream. The differences are made plain in the following table:—

	Free Ammonia. Parts per 100,000.	Albuminoid Ammonia. Parts per 100,000.	Ratio.
Above Paterson	0·00	0·021	Infinite.
Below Paterson	0·2075	0·225	1 to 1
Below Passaic tail-race	0·0745	0·0215	3·5 to 1
16 miles below Paterson	0·0005	0·026	1 to 52

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*For complete list, see *Jour. Amer. Chem. Soc.*

Since this time, during a period of eighteen months, there has never been an occasion when the water taken monthly at the Jersey City intake contained as much free ammonia as albuminoid ammonia. This remark is true of seasons when the flow of water being at its minimum and polluting agencies at their maximum efficiency; the water supply was otherwise adversely reported upon.

In 36 analyses of waters of the Brandywine river and certain other streams proposed as new sources of water supply, which I made in the year 1882, at the request of the City Councils of Wilmington, Del., there was not a single instance in which the free exceeded the albuminoid ammonia. The ratio varied between 1 to 43 at Rockland dam, which is the point I recommended as the best from which to draw the future water supply, to 1 : 1.2 at certain spots when the influence of trade and other pollutions became manifest.

Without detailing here the results of examination of many other streams, it is sufficient to say that the ratio of the free ammonia to the albuminoid ammonia usually varies in river waters from 1 : 2 to 1 : 10, and even higher amounts for the albuminoid ammonia. If the free ammonia exceeds, it can ordinarily be assumed that a very large amount of the *products* of decomposition derived from trade and sewage pollution are present. In such cases the absolute amount of albuminoid ammonia is also very considerable. But, as previously stated, the absolute amount of albuminoid ammonia in the Schuylkill river at the time when the non-potability occurred, though much exceeding the "limit of purity" in a river water whose free ammonia is at the same time very high, was not extraordinarily great. For this reason the excess of free ammonia indicates not only the fact of pre-existent trade and sewage contamination, but taken in connection with the other facts developed during the course of this investigation, has a special significance which will be explained farther on.

OXYGEN REQUIRED TO OXIDIZE THE ORGANIC MATTERS.

That the nauseous taste and smell was not due to the mere fact of an excess of decomposable organic matters is rendered still more probable by the small percentage of oxygen required to effect this oxidation. It is little more than one-fourth the amount of oxygen required on June 24, 1881, when the water was excellent, both in taste and smell.

NITRITES AND NITRATES.

A peculiarity of the same description exists with regard to the ratio between the nitrites and nitrates as between the free and albuminoid ammonia, in that the former is present in large amounts in all the samples. The origin of the nitrites is twofold. They are due either to direct oxidation of the nitrogenous organic matter—this oxidation stopping short of its proper final stage, which is the complete conversion into the form of nitrates—or they are formed at the expense of the nitrates already existing, by their reduction in presence of excess of readily oxidizable organic matters.

Both modes of origin are indicated in the present instance, and both point to the same conclusion that there was an excess of organic matter beyond what could be oxidized under the existing circumstances.

On account of the extreme instability of the nitrites, they are usually converted almost entirely into the form of nitrates, and leave behind but little more than a trace of their presence. Their large percentages in these samples indicate, therefore, a retarded or arrested oxidation.

COMPLETE ANALYSES OF THE SCHUYLKILL WATER SUPPLY.

	POTTSTOWN, January 10, 1883.		FAIRMOUNT, January 9, 1883.	
	No. 226.		No. 228.	
	Parts per 100,000.	Grains per gallon.	Parts per 100,000.	Grains per gallon.
Lime	3·593	2·095	3·520	2·053
Magnesia	1·515	0·884	1·034	0·603
Oxide of iron and alumina	0·134	0·077	0·264	0·154
Ammonium hydrate	0·019	0·012	0·040	0·023
Sodium chloride	0·590	0·344	0·930	0·542
Potassium chloride	0·180	0·105	0·187	0·109
Carbonic anhydride	0·780	0·455	0·710	0·404
Sulphuric anhydride	2·300	1·341	1·890	1·1
Silicic anhydride, and insoluble matters	1·289	0·752	1·950	1·137
Phosphoric anhydride	trace.	....	trace.	
Nitrous anhydride	0·008	0·005	0·008	0·005
Nitric anhydride	0·560	0·327	0·640	0·373
Inorganic matter	10·968	6·393	11·173	6·523
Total solid matter in solution	18·000	10·497	18·500	10·789
Organic matter (by difference)	7·032	4·104	7·327	4·266

CHLORINE.

The percentage of chlorine is somewhat high, and is relatively greater at Fairmount than it is at Roxborough, Norristown, and Pottstown. It is also higher than at other seasons when the character of the water has been better. All these facts are in accord with what would occur from sewage contamination, but do not aid us materially in discovering the cause of the January disorder.

TOTAL SOLIDS AND COMPLETE QUANTITIVE ANALYSIS.

The determinations of the amounts of saline bodies and organic compounds which exist in the water in a state of solution, and are left behind as a residue upon evaporating 100 cc. of the water to dryness and drying at 110°C., throw no light upon the present question. They merely show that the amount of substances in solution is greater by ½ part in 100,000 at Fairmount than in the upper portion of the stream. It is not unusual to strongly heat these residues and set down their losses in weight as organic and volatile matters. For a variety of reasons the results thus obtained are so inaccurate as frequently to mislead, and for this reason have not been made use of in the present difficult inquiry. Instead, I have given below the results of two complete analyses of the mineral constituents. The difference between the sum total of these mineral constituents and the total solids in solution is regarded as representing the organic matter approximately. Unfortunately, no accurate determination of the total amounts of the very complex and very various organic bodies present in natural waters is possible in the present state of our knowledge. The results here given represent the closest approximation to the truth which I was able to arrive at, and, I think, are sufficiently correct to serve as a trustworthy basis for reasoning.

An examination of these complete analyses shows that the lime, magnesia, carbonic anhydride and sulphuric anhydride are all less at Fairmount than at Pottstown. They have probably been precipitated out of solution on account of the relative insolubility of the carbonates and sulphates of lime and of the carbonate of magnesia. The increased amounts of sodium and potassium chloride, of ammonium carbonate, of nitrous and nitric anhydrides, would all be in accordance with the fact of contaminating with sewage and trade pollution in the lower portion of the stream, as would also be the slightly increased amount of organic matter, shown in the analysis of the Fairmount, as compared with the Pottstown water. But this increase is not so important as the fact that the organic matter, even in the upper portions of the stream, was very considerable, amounting to over 7 parts in 100,000. And what is important for us to note here is that to this considerable burden of organic matter, which might or might not be of unwholesome character, was added to the customary increment of pollution from sewers and factories in the lower portion of the stream. As to the origin of this organic matter, the following letter is important:

"*Reading, January 11, 1883.*

"DR. WM. H. MCFADDEN,
Chief Engineer Water Department.

"DEAR SIR:—Referring to your favor of 9th inst., asking for the facts regarding the present condition of the Schuylkill, I have to say in reply that all the dams of the Navigation Company above the Blue mountains, from No. 7, at Schuylkill Haven, to No. 16 (Blue mountain), were drawn between December 18th and 23d, and they remain so drawn at this time. The water was let out from each dam by means of sluices in them provided for that purpose, and canals connected with them were emptied at the same time. All these dams had ice upon them from 4 to 6 inches in thickness when drawn. Between the Blue Mountain and dam No. 22, North Reading, none of the dams have been drawn; they are now and have been covered with ice about 6 inches thick, since the middle of December.

"Ice began to be formed soon after the 26th of November, and the obstruction was complete as early as the 4th of December.

"Dams Nos. 23 and 24 (Poplar Neck and Lewis) below Reading, the latter known as the big dam, were drawn respectively on the 29th of December and January 1st, and there was very little ice on either at these times. The dams between No. 24 and Fairmount, six in number, have not been drawn, but have all been more or less obstructed by ice since December 4th, varying in thickness from 2 to 5 inches.

"The flow of the river has been much below the usual minimum, both during the fall and ever since winter set in, and the rain-fall in the valley has not been more than half of what is usual during the same period.

"The dams not drawn, nevertheless, have all continued to run over, but with a flow scarcely more than that of the low water of summer, whilst the dams below 'Lewis,' or 'big dam,' have not been drawn, all the canal levels which they supplied have been emptied. One series of these levels, 22 miles in length, supplied from the 'big dam,' was drawn out about the 16th of December, and furnish a very large body of pure water to the river. Another, the five-miles level, opposite Royers' Ford, was drawn on the 23d of December. This level receives the drainage from the wood-paper works at Spring City. The level opposite Phœnixville, 4 miles in length, was drawn out on the 22d of December.

"Yours, very respectfully,

"JAS. F. SMITH."

In commenting upon this letter, the Chief Engineer emphasizes the three most important facts thereby elicited.

1. The small rainfall in October, November, and December, and the very small flow of the river.

2. The emptying of the Schuylkill canals and eleven dams thereon.

3. The complete covering of ice on the Schuylkill river, the canals, dams, and tributaries.

Whilst the first two points throw much light upon the origin of the large percentage of organic matter, they cast but little upon its character,—whether it was necessarily wholesome or unwholesome, whether it imparted the bad taste and smell. With reference to possible unwholesomeness we must remember that the organic matter which contains nitrogen is the portion most important to study. The amounts of albuminoid ammonia (0·0145 parts to 0·02375 parts) indicate that this constitutes only a small fraction. If we assume, along with the author of the albuminoid process, that the nitrogenous organic matter may be estimated as ten times greater in amount than the albuminoid ammonia, this fraction would not exceed 0·2375 parts in a total of 7 parts in a thousand. I am aware that the experiments by which this proportion was established have recently been repeated by Preusse and Tiemann,* mostly upon artificial organic compounds, far more stable in their nature than the putrefiable substances, the estimation of which especially concerns us in hygienic investigations of water supplies. These experiments, which were less extended and elaborate than those of Wanklyn, merely confirmed his results. Their conclusion that the process gives us no indication of the absolute quantity of nitrogenous organic substances, no more invalidates the process than the analogous results they found by the permanganate method of estimating organic matter militates it. And yet, whilst they obtained less decisive results by permanganate process, urea for instance not being at all oxidized, they placed great stress upon the indications afforded by the permanganate method. It may, likewise, be inferred from experiments identical in character with those by which Wanklyn assumed that the disintegrating animal refuse in water might be fairly estimated as ten times its albuminoid ammonia, that its total organic matter is about 20 times greater than the oxygen in the permanganate required to effect its oxidation. We have already seen that the organic matter in the Pottstown sample amounted in all to 7·032 parts per 100,000, and in that from Fairmount to 7·327 parts. Estimated by the above rule, the relative amounts of organic matter would have been 4·0 parts in 100,000 and 7·4 parts respectively. Fallacies inherent in the permanganate method, and inductions based thereon, make this lack of concordance probable. Nevertheless, it may safely be assumed that of the total of 7 parts of organic matter per 100,000, not more than 0·5 parts were readily decomposable organic substances, or were derived from sewage.

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* Ber. der deutsch. chem. Gesell, xii, 1906.

DISSOLVED OXYGEN.

I did not attempt to determine the oxygen in the samples collected when the water was at its worst phase, the samples having stood several days. But the determinations made upon the fresh samples, collected by myself and analyzed with least possible delay, bring into prominence certain points which bear directly upon the vital question of the present investigation. These relate, in the first place, to the smaller volumes of oxygen in the samples as compared with the volumes which should have been present in case the water had been completely aerated, and, in the second place, to the different volumes of oxygen in the pairs of samples collected at the same spot, but the one from the top, the other from the bottom of the stream.

The largest volume in any of the six (Nos. 230, 235) is that contained in No. 234, the sample taken from the bottom of the stream at Roxborough basin. It is 5·64 cubic centimeters in a liter of the water measured at 15° C. But this amount is nearly a cubic centimeter less than I found to be present in a liter of distilled water, artificially aerated by a current of filtered air, and which contained 6·51 cc. of oxygen.

A liter of No. 230, similarly aerated, had its volume of oxygen raised from 4·41 cc. to 6·3 cc., and another liter of No. 230, aerated by mere exposure for a number of days, in flasks plugged with cotton wool, to the atmosphere, had its volume of oxygen increased to 6·2 cc.

These aerated samples were afterwards subjected to sun-light, in the presence of nitrate of silver, when it was found that the amount of oxygen required to oxidize the organic matter in that portion of No. 230, which had been aerated by a constant current of air, had been reduced from 0·218 part in 100,000 to 0·044 part. The organic matter in the other sample of No. 230, aerated merely by exposure to the atmosphere, had been reduced from 0·218 part to 0·103 part.

These facts, it appears to me, are conclusive both as to the lack of oxygen in the samples collected and the effect of oxygen on that small portion of the total organic matter which was susceptible of easy decomposition or putrefaction and of as easy oxidation.

Very noteworthy, also, are the differences between the volume of oxygen contained in the corresponding series of samples taken from the top and bottom of the stream, the oxygen being uniformly greater in the bottom water. The differences are real, whatsoever opinion may be obtained as to their cause. The results being surprising, the determinations were oft repeated, but the closely concordant figures were decisive as to the fact of the larger volumes of oxygen being present in the samples taken from the bottom. It is also noteworthy, that in the Roxborough samples the volumes of oxygen are greater in both top and bottom sample, than in the corresponding samples at Spring Garden and Fairmount.

The bearing of the above facts upon the great question, kept constantly in view in this investigation, can be best appreciated in the light of the results obtained by certain European chemists, more especially by M. Dumas, his examinations beginning with the river Seine, above Paris, and extending to Rouen, about one hundred miles below. He found that the river water contained at the first named point, 9 cubic centimeters in a liter; at Point d'Ivry, near the upper border of the city, 8 cc.; at Point de la Tournelle, near the middle of the city, 8 cc.; below the city, and above the outlets of main sewers, 6 cc.; at outlet of lower main intercepting sewer, 2 cc.; at Epinay, a point located below all sewers, 1 cc.; at Poissy, 17 miles below Epinay, 6 cc.; at Vernon, 27 miles below Poissy, 9·5 cc., and at Rouen, 35 miles still lower down, even more than in the waters above Paris, or 10·5 cubic centimeters in a liter.*

Still more striking results were obtained by M. Gerardin, who extended the inquiry so as to embrace the three following topics:

1. A determination of the amount of oxygen held in solution.
2. An observation of green plants and aquatic mollusks.
3. A microscopic examination of algæ and infusoria.

It is claimed that the results obtained by these three methods were identical, and that, where the water was clear, with abundance of fish, water-cress, etc., it contained a correspondingly large amount of oxygen; while in places where the dissolved oxygen was small, fish and the higher types of aquatic plants were wanting, and certain low forms of vegetable growth had taken their place. The river Vesle, in France, from Rheims to Braisne, was taken as the field of observation. It was studied over a distance of 37½ miles, during which it received the sewage of one large town (that of Rheims), amounting to 4,180,000 gallons, and other impurities. Above Rheims the water, which was clear, wholesome and with abundance of fish, charas, water-cress, iris, etc., contained 1 cubic inch of oxygen in 100 cubic inches.

In passing through a suburb above Rheims, the Vesle received the refuse of some dye works, which colored the water; and in place of the fish and water-cress, Sparganium simplex made its appearance. At a point where the water had received the contents of the five principal sewers of Rheims, the water was thoroughly polluted, and contained but ·05 cubic inch of oxygen in 100 cubic inches. Two species of algæ, the Beggiatoa alba, and the Oscillaria natans were developed largely, the latter to such an extent, that the whole surface of the sluggish water was covered with a thick, blackish coat. This coat was seemingly so solid, that animals, and even men, ventured upon it, mistaking it for terra firma. Above the mill at Macan, when the oxygen had increased to 0·74 cubic inch, the two varieties of algæ mentioned above, had disappeared, and the bed of the Vesle was covered with a long, whitish algæ, called Hypheothrix. At Compensé mill, the oxygen had increased to 0·8 cubic inch, the hypheothrix had almost completely disappeared, and the Sparganium simplex was again abundant. Below this point the amount of oxygen increased, and with it a corresponding change took place in the vegetation, until, at Braisne, the water contained 1 cubic inch of oxygen per 100 cubic inches, all traces of pollution had disappeared, and fish and water-cress flourished. From this it would appear that a properly aerated and pure water showed, when polluted, the amount of pollution by a corresponding diminution of oxygen, by the appearance of Sparganium simplex, Spirogyra, Hypheothrix, Beggiatoa and Oscillaria, and progressive improvement by a corresponding increase of oxygen, and the appearance of these plants in reverse order.

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* It is probable that these figures for dissolved oxygen, which were obtained by M. Schutzenberger's process, are all too high. But the ratio between their relative values is probably approximately correct, and is sufficient to establish the point under consideration.

ACIDITY AND ALKALINITY.

Potable water should have a neutral reaction. This was not the case with the Schuylkill water. It was decidedly acid in its upper portion (January 10), less so in its lower portion (January 9), and in the interval between January 9 to January 13, its reaction changed from acid to alkaline. Six days later when from all accounts its taste and smell had much improved, it was neutral. This change of reaction could not take place without influencing the constitution of the water, since it would tend to precipitate various bodies held in solution. It is difficult to speak more precisely on these points, since the determination of the acidity and alkalinity of potable waters has been hitherto generally overlooked, and from the lack of data it can only be said that this change of reaction was associated with, and favorable to a rehabilitation of the potability of the water supply.* What we must emphasize is that the water coming down the stream after the 9th of January was of a very different character from that of the water before this date. The acid water had all gone by the Fairmount pool before the 13th of January, since at the latter date the water was no longer acid but alkaline. In other words, the influence of the limestone waters flowing into the Schuylkill was more pronounced on the 13th of January than the influence of the acid waters emptying into the stream in its upper portion at points above where the limestone-bearing tributaries join the Schuylkill. This being the case, the origin of the bad taste and smell is likewise connected to a certain extent with the upper portion of the river. It was due in part at least to other causes than the irruption of sewage and factory waste into the Roxborough, Spring Garden, and Fairmount pools.

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* See a valuable contribution to this subject by Dr. C. M. Cresson and Mr. H. W. Mitchell in pamphlet "Results of Examination of Water from the River Schuylkill, Phila., 1875."

COLOR, TASTE, SMELL, AND HYGIENIC EFFECTS.

Though none of the samples were colorless as compared with distilled water, the estimation of the precise tinge was of no importance in this investigation.

The taste and smell are difficult to define since subjective impressions cannot well be described unless they originate from familiar substances. Many ascribed to the water the odor of carbolic acid; others that of chloride of lime; most likened it to something of an oily, greasy or fatty character.

A large quantity of the water was tested for carbolic acid, but not a trace was found, nor any other indication of the presence of bodies derived from coal-tar or gas works refuse.

No metallic poisons were present, nor any substance like chloride of lime.

Letters addressed to eminent physicians in Philadelphia, elicited the uniform response that no connection could be established between the character of the Schuylkill water supply in the month of January and any case of disease within their practice. The following table compiled by order of W. H. Ford, M. D., Chairman of the Sanitary Committee, Philadelphia Board of Health, may be studied by any who feel able to draw satisfactory conclusions therefrom.

Deaths from some of the principal zymotic diseases in Philadelphia for sixteen months, commencing with November, 1881.

DISEASES.	MONTHS.															
	November, 1881.	December, 1881.	January, 1882.	February, 1882.	March, 1882.	April, 1882.	May, 1882.	June, 1882.	July, 1882.	August, 1882.	September, 1882.	October, 1882.	November, 1882.	December, 1882.	January, 1883.	February, 1883.*
Cerebro-spinal meningitis	3	10	3	2	10	6	7	4	4	7	4	2	.....	2	5	3
Cholera morbus	1	1	.....	1	1	......	1	1	18	33	6	1	......	......	......	1
Diarrhœa	10	11	6	12	21	14	12	3	25	35	13	10	9	8	11	8
Diphtheria	75	64	83	55	48	41	66	55	55	53	95	112	137	132	127	51
Dysentery	1	7	2	7	5	2	2	6	10	16	11	7	3	1	2	2
Typhoid fever	85	67	60	56	5	79	76	57	28	52	49	52	33	53	57	28
Inflam'n of stomach and bowels	25	35	12	30	46	32	35	38	47	88	54	47	30	32	30	23

* February, only three weeks.

MICROSCOPIC EXAMINATION.

In pursuance of the methods of Koch, and after a plan suggested by Dr. R. Angus Smith, 50 cubic centimeters of each sample were added to 25 cc. of a 2½ per cent. solution of gelatin in distilled water, 5 mgrm. of sodium phosphate added to each, and the flasks containing the solutions allowed to stand in a warm place. After five days, liquefaction began on the upper surface of the jelly-like contents of one flask, that containing No. 230, and subsequently one after another the remaining flasks also became filled with micrococci and bacteria. This mode of inquiry afforded no aid in the study of the present problem.

THE GRAPHIC CHART.

I have appended to this report a graphic representation, which puts in clearer light the obtained results. It presents sanitary analyses of ten samples collected January, 1883, and, for comparison, that collected June 24, 1881. Also, complete analyses of the inorganic matter in the Pottstown water (January 10) and the Fairmount water (January 9). Constituents of the same order of magnitude are represented on the same scale; the upper third of the map being given to free and albuminoid ammonia and nitrites; the middle to required oxygen, nitrates and chlorine; the lower third to dissolved oxygen. In the last, the scale represents volumes or parts of cubic centimeters of oxygen per liter of water.

Inspection shows that the *free ammonia* was least at Pottstown. The curve rises and crosses above that for the albuminoid ammonia at Fairmount, January 13, and does not fall below it until it represents the bottom water in Roxborough pool, January 20. For the second series of samples, the maximum elevation of the free ammonia curve is found at Spring Garden basin.

Albuminoid ammonia rises to its maximum at Fairmount forebay January 9.

For reasons previously explained, the curve of the *required oxygen* does not repay study, which represents the results obtained by the permanganate process.

Nitrites show maxima at Fairmount and Spring Garden.

Nitrates are greatest at Roxborough, and what is striking, at the same point the curve for the nitrites falls, as though the reduction due to the incursion of fresh sewage was less at that point.

Chlorine rises steadily with the flow down the river.

Dissolved oxygen rises and falls at top and bottom of the river, but shows a relative rise in both for the Roxborough samples.

4. LIGHT THROWN BY THE RESULTS UPON THE ORIGIN OF THE JANUARY TASTE AND SMELL.

It has been stated previously that the mere fact of sewage contamination is insufficient to explain the taste and smell. The anomalous accumulation of the products of decomposition; the free ammonia exceeding the albuminoid; the reduction of the nitrates to the form of nitrites, instead of remaining in the former form; the deficiency of oxygen in all samples as compared with the normal amount; the completer oxidation of the decomposable organic matter when the samples were allowed to absorb their full complement of oxygen—all of these facts are significant of a different explanation. This is, that the taste and smell were connected with a state of partial and arrested oxidation, and of incomplete aeration. Moreover, the bodies which gave rise to the unpalatability were products of decomposition of organic substances contained in the water, or deposited at the bottom of the stream, the nature of these bodies being determined by the fact of their being formed by processes of putrefactive decay out of contact with oxygen. Under these conditions it is well known that hydrocarbons belonging to several isologous and homologous series are formed, the lower members of which are gases; the members of greater molecular condensation, oils; and the highest, solids. The most familiar instance is that of marsh gas, which is being constantly liberated from vegetable matter decomposed at the bottom of ponds out of contact with air. Another familiar instance is that of the oil frequently seen floating on the surface in similar localities, and originated in the same way, but differing from marsh gas by greater condensation of molecular structure. When this decomposition occurs under water containing (like that of the Schuylkill river) sulphates, these sulphates undergo reduction, and sulphuretted hydrogen and sulphuretted hydrocarbon compounds are liable to be found, all of which compounds are foul-smelling and ill-tasting.

Whilst the opportunities afforded me for investigation (the inquiry having been put into my charge only after the crisis of the disorder had passed and the great body of the unpotable water had gone by Fairmount pool) were too limited to permit me to offer the above, except as a probable explanation, yet I trust I may not be thought lacking in scientific caution so to do. The explanation accounts for the combustible gases found beneath the covering of ice, and which, according to the testimony of Professor Houston, were in sufficiently large percentage to be set fire to.*

It accounts for the volatile oily bodies so generally complained of, so persistent as to communicate their taste to the food cooked in them, and to diffuse through the house and kitchen their disagreeable odor. It explains their connection between the acid water of the upper Schuylkill and the contemporaneous accession of unpalatability, this upper water, already charged with products of decomposition accumulated in ice-covered dams and canals, being further deteriorated by bodies peculiarly susceptible to putrefactive decay, and to an extent exceeding the maximum limit of permissible sewage contamination in the lower portions of the stream.

5. QUESTIONS RELATING TO THE DETERIORATION OF THE WATER SUPPLY.

Such a conjunction of untoward circumstances as resulted in this January cachexy of the Schuylkill water supply seldom occurs. For this reason its consideration may be dismissed until opportunity is afforded for a complete investigation of similar disorders and for discovery of appropriate remedies.

At present it is more important to note that the water in the Fairmount and Spring Garden pools often deteriorates to a point below the maximum limit of admissible impurity. And whilst the evidence afforded by the single analysis of the water in the Roxborough pool, which was only incidentally made in the course of this investigation, is much in favor of the latter, yet the relative character of the Roxborough water can only be established with certainty by more extended research.

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* The following letter, received long subsequent to the publication of the original report, gives an interesting account of these remarkable phenomena:

PHILADELPHIA, *June* 6, 1883.

DR. ALBERT R. LEEDS,

DEAR SIR:—In reply to your letter of inquiry, we write to say that you have been correctly informed concerning the inflammable gas. It was first shown to us by Mr. Alan Gentry, of Germantown, and we have subsequently repeated the experiment on several occasions. The gas was contained in white hollows under the surface of the ice, and whenever we noticed one of these, we punctured it with a penknife and applied a match. The gas took fire readily, and burned with a blue flame, yellow at the top. A noteworthy fact in connection is that the gas was found only on the western bank of the river, where the water is shallow, and the bottom of deep black mud. The flames were ordinarily about six inches high, but once we obtained one fully a yard high. They burned usually for about two minutes.

W. A. MACKIE,
E. E. MATHER.

THE CHEMISTRY OF THE PLANTÉ AND FAURE ACCUMULATORS.*

By J. H. Gladstone and Alfred Tribe.

(Continued from vol. cxv, page 68.)

Part V.—1. influence of strength of acid.

In the second part of this communication, see this *Journal*, vol. cxiv, p. 223, when treating of the charging of the cell, we pointed out that in the electrolysis of dilute sulphuric acid between lead electrodes, two totally different reactions might be obtained. The positive metal becomes thinly coated with lead sulphate when the current employed is of small density, but with lead peroxide when the density of the current is of greater magnitude. This latter action is, of course, what takes place in the ordinary formation of a Planté battery. The chemical change, therefore, which goes on at the positive electrode is to a certain extent dependent upon the strength of the current. It appeared also of both theoretical and practical interest to determine whether the chemical change was also influenced by the strength of the acid employed. Our experiments consisted in passing a current of uniform strength, about 1 ampere, between electrodes of lead, 12 square inches in size, in varying strengths of sulphuric acid, and estimating in each case the amount of oxygen fixed by the positive electrode. We determined this for successive five minutes of time, and as such actions are not always very uniform, we made in each instance more than one experiment. The results are given in the following table:

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* From London *Nature.*

Strength of acid.	Expt.	Percentage of oxygen fixed.				
		First 5 mins.	Second 5 mins.	Third 5 mins.	Fourth 5 mins.	Total.
1 to 5…………	I.	38·1	28·6	28·6	33·3	128·6
	II.	39·5	30·2	25·6	30·2	125·5
1 to 10………	I.	43·4	38·7	29·2	31	145·3
	II.	44·1	39·3	29·3	31·9	147·6
1 to 50………	I.	48·3	39·6	35·3	22·4	145·6
	II.	46·2	43·9	23	30	143·1
	III.	54	40	35·3	35·5	165
1 to 100………	I.	42	38·3	33·9	29·5	143·7
	II.	42·4	40	37·8	35·5	155·7
	III.	51·1	44·2	34·9	34·9	165·1
1 to 500………	I.	46·6	32·6	27	27	132·6
	II.	46·4	27	27	18	118·4
1 to 1,000……	I.	90·6	81·1	76·4	57·5	305·6
	II.	90·8	77	72·3	63·1	303·2

It appears from this that the strong sulphuric acid (1 to 5) is not quite so favorable to the action as the more dilute (1 to 10), but that between this latter proportion and 1 to 500 there is no great difference in the amount of oxygen fixed, and therefore of corrosion of the plate. The appearance of the plate in every instance indicated the formation of peroxide lead only. With sulphuric acid diluted with 1000 parts of water, the amount of oxygen fixed, and therefore of corrosion, was at least doubled, while the chemical action was very different. On parts of the electrode, streaks of a mixture apparently of the yellow and puce-colored oxides were seen. On other parts a white substance formed and was easily detached, falling in clouds into the liquid. Where this latter action took place, the plate was visibly the most corroded. This white substance gave on analysis SO_4, equivalent to 73·6 per cent. of lead sulphate, suggesting the idea that it was a basic sulphate of the composition $2PbSO_4,PbO$, which would require 73·1 per cent. As the peroxidation of the lead is required, and the corrosion of the plate is to be avoided as much as possible, it is evident that this extremely dilute acid must be avoided. It has already been shown that if the sulphuric acid is entirely removed from solution, as sometimes happens in an accumulator, the lead is simply converted into the hydrated protoxide, and therefore corroded without any good effect.

2. FUNCTION OF HYDROGEN.

In the formation of a secondary cell, after the complete reduction of oxide or sulphate to metallic lead, bubbles of hydrogen gas are seen to escape from the lead plate. It has been assumed that a portion of this is occluded by the lead, or in some other way enters into association with it, and it has been supposed that this hydrogen compound may play an important part in the subsequent production of electromotive force. It therefore appeared desirable to obtain experimental evidence as to whether hydrogen is so absorbed. The process we adopted for this purpose was founded upon the observation of Graham that hydrogen associated with palladium reduced ferri- to ferro-cyanide of potassium, and that generally in the occluded condition the element was more active chemically. We had previously ascertained that hydrogen associated with other elements, as platinum, copper and carbon, was capable of reducing potassium chlorate to chloride. This method seemed to give trustworthy results, and therefore we applied it in this instance. As the result of several trials, however, we found that the amount of hydrogen associated with the reduced lead was almost inappreciable. Small as this quantity is, however, it is by no means impossible that it may be the cause of the exceedingly high electromotive force observed for the first few moments on joining up a completely formed cell immediately after its removal from the circuit of the charging current. This, however, may be due, as Planté imagined, to the gaseous hydrogen itself. The principal if not the only function of the hydrogen of the water or sulphuric acid is therefore that of reducing the lead compounds.

By a totally different process Prof. Frankland has very recently come to the same conclusion as ourselves in regard to the exceedingly small amount of occluded hydrogen.

3. EVOLUTION OF OXYGEN FROM THE PEROXIDE PLATE.

Planté noticed a small escape of gas from the negative plate of his cell immediately after its removal from the influence of the charging current. This he attributed to a decomposition of water by means of local circuits between the peroxide and the subjacent lead plate in contact with it.

The explanation we gave in our first paper (this *Journal*, vol. cxiv, p. 219) of the local action which goes on at the negative plate does not account for the escape of any gas—either oxygen or hydrogen. We therefore thought it of interest to ascertain the nature, and if possible the origin of the gas noticed by Planté.

We found that the escape of gas from a Planté negative plate was very slight, and soon ceased; but we observed that it became much more pronounced when the temperature of the electrolytic liquid was raised. In order to get a sufficient quantity of the gas for examination, we prepared a negative plate according to the procedure of Faure, and then heated it in dilute acid, with an arrangement for collecting the gas as it was evolved. The amount of gas was still very small in comparison with that of the peroxide, but a sufficient quantity was collected to enable us to ascertain that it was oxygen. We next heated some of the electrolytic peroxide apart from the lead plate, and again noticed a similar evolution of gas, which was also found to be oxygen. This shows, therefore, that it was not a result of local action.

The gas has generally some odor of ozone, and on testing the dilute acid between the plates of a Planté cell we always found traces of something that bleached permanganate of potassium, and which might be either ozone or peroxide of hydrogen.

The origin of the gas noticed by Planté may be easily attributed to the oxygen which always passes off in quantity from the peroxide plate during the process of "formation." It is only necessary to suppose that some of this becomes condensed on the peroxide, and is gradually eliminated from it when the surrounding conditions are changed. But the matter is capable of another explanation. If peroxide of hydrogen be really formed in the liquid, it will exert its well-known influence on higher oxides, namely, that of reducing them and itself at the same time. As a matter of fact, if peroxide of lead is dropped into peroxide of hydrogen, oxygen is evolved.

4. TEMPERATURE AND LOCAL ACTION.

Planté has recently pointed out that an elevation of temperature facilitates the formation of his secondary cell (*Comptes Rendus*, August, 1882). The character of the chemical changes which took place at the negative plate led us to think it exceedingly probable that this increase in the rate of formation arose from an augmentation in the amount of local action. Experiment showed such to be the case. Pairs of similar negative plates on Planté's model were allowed to remain in repose at 11°C. and 50°C. respectively, and the formation of the white sulphate was visibly more rapid at the higher than at the lower temperature. The same is also true with negative plates prepared by Faure's process. Thus we found that two similar plates kept in repose for an hour, the one at 11°C. and the other at 50°C., formed by local action 2·6 and 7·4 per cent. of lead sulphate respectively. On two other plates the proportions were 7·6 and 9·5 per cent. respectively. These observations of course by no means exclude the idea that an increase of temperature may facilitate the other chemical changes that take place in the formation of a lead and lead-oxide cell.

PEMBERTON'S METHOD FOR THE VOLUMETRIC ESTIMATION OF PHOSPHORIC ACID.

By Prof. G. C. Caldwell.

[From advance sheets of the Second Report of the Cornell University Experiment Station.]

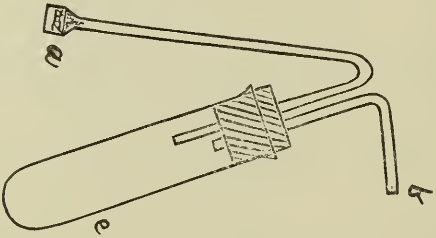
Mr. H. Pemberton, Jr., has described (Journal Franklin Institute, March, 1882, p. 184) a new method for the volumetric determination of phosphoric acid, especially in fertilizers, by a standard solution of ammonium molybdate; he adds the precipitant to the suitably prepared solution of the fertilizers as long as a precipitate is produced, the final tests for further precipitation being made with small filtered portions of the solution under examination. He prepares his standard solution by dissolving 89·543 grams of ordinary ammonium molybdate in 1000 cc. of water; each cubic centimetre of such a solution precipitates 3 milligrammes of phosphoric anhydride. The solution of the phosphate is freed from silica and organic matter, then made up with as little excess of acid as possible, and just neutralized with ammonia; 2 cc. of nitric acid (sp. gr. at least 1·4) and 10 grams of ammonium nitrate are added, and the solution is heated to 60° Cent., or above, preparatory to adding the molybdate; it is necessary to apply the filtration test only towards the end of the operation, when it becomes difficult to discern the effect of further addition of the molybdate, even in the supernatant liquid that has been somewhat clarified by standing for a minute or two.

The frequent need of the determination of phosphoric acid in fertilizers, the absence of any thoroughly reliable volumetric method for this determination, and the length of time required for the gravimetric method, when the acid must first be precipitated by molybdate, all unite to give special interest to such a method as this, in which the molybdate itself, giving so sharp a reaction for the acid, is used directly in the standard solution.

With one modification in the preparation of the standard solution, and another and more important one in the mode of filtering out the test-portions, the process has satisfactorily sustained a series of careful tests in the laboratory of the University. As to the preparation of the standard solution, Pemberton found that the ordinary ammonium molybdate of the druggists was sufficiently pure to give the standard directly; in order to clear away the slight turbidity which the salt usually leaves he added a little ammonium hydrate. It was observed by Dr. Newbury, then analyst to the Station, that in the case of the molybdate supplied to us, a notable degree of alkalinity was communicated to the solution by the quantity of ammonium hydrate required to clarify it, and that, consequently, the necessary acidity produced by the nitric acid added in the beginning to the solution of the phosphate, became so much reduced towards the end of the titration after a considerable quantity of the molybdate had been added, that the results were unsatisfactory; in some instances the solution even became slightly alkaline before the precipitation was completed. In order to avoid this difficulty the molybdate solution was filtered after the addition of a few drops of ammonia at the most, and then standardized by a solution of phosphorus salt in which the phosphoric acid had been carefully determined by molybdate and magnesia mixture in the usual manner.

As to the manner of taking out the final test-portions, even when this operation is performed as described by Mr. Pemberton, this method of determining phosphoric acid is unquestionably more expeditious than the usual precipitation method; but the necessity of filtering out each test-portion in the ordinary way through a filter has its evident objections. For this filtration we have used in this laboratory with entire success a little contrivance that was applied with like success some years since in the determination of sulphuric acid by a standard solution of barium chloride, in a modification of Wildenstein's method as described by Fresenius. The apparatus, as still further improved, more recently, is shown in the adjoining figure. The internal diameters of the bent tubes *a* and *b* should be about one millimetre, and that of the mouth at *a* about five millimetres. The length of the arm *a* may of course be adapted to the depth of the beaker used. To prepare the filter for use a small perforated platinum cone, or a tangle of fine platinum wire, is crowded into the throat of *a* so that it will not fall out when the mouth of the tube is downwards; suction is applied at *b* by a rubber tube to the mouth or connected with the exhaust; *a* is dipped for an instant only in a very thin asbestos pulp, and the suction is continued while the filter is then plunged into water and till the wash water comes through clear; it is then ready for use.

In using it, the only precaution to be observed, and that is an essential one, is never to plunge the filter into a liquid unless suction is applied to it, and to continue the suction as long as it remains in the liquid; otherwise the asbestos and cone may fall out of the tube. The filter being thus withdrawn, the liquid contained in it and in the tube *a* is drawn over into the test-tube; two or three drops of the molybdate solution are run directly into *c* to test for complete precipitation, the rubber cork and its two tubes being meanwhile conveniently hung on a hooked wire attached to the lamp stand; the test being completed by heating the contents of the test-tube just up to boiling, the liquid is poured back into the beaker and the tube is rinsed also into the beaker with a very little hot water; when the next test-portion is to be filtered out the first filtrate drawn over is poured back into the beaker, thus using this portion to wash out of the filter and tube the last portions of liquid adhering to it from the previous filtration. The final reaction is so sharp, that, towards the end of the titration, we have found it sufficient to add to the solution in the beaker only the few drops of molybdate added to the test-portion.



In the following table the results are given of our tests of this method of determining phosphoric acid. The solutions of the phosphates analyzed and of the molybdate were prepared by Dr. Newbury, and the gravimetric determinations by the ordinary molybdate method were also made by him. The several volumetric tests following were made, using these solutions, by Dr. Newbury (I), Dr. S. M. Babcock (II), then instructor in the chemical department, and myself (III), and in every case in entire ignorance of the results obtained by the others. Mr. Furry (IV), at present the analyst of the station, prepared his own solutions throughout.

Station Number.	I.		II.	III.	IV.
	Grav.	Vol.	Vol.	Vol.	Vol.
235........................	....	13·14	13·27	....	13·13
		13·14	....	....	13·18
					13·15
					13·12
259........................	12·47	12·33	12·39	12·44	12·34
	12·41	12·33	....	12·45	
				12·47	
261........................	9·15	9·26	9·08	9·20	9·34
	9·21	9·26	....	9·05	9·37
				8·97	
				8·97	
272..................... ...	13·69	13·57	13·75	13·82	
	13·82	13·57	....	13·81	
		13·69	....	13·72	
		13·69			
		13·63			

Most of these results speak well in favor of the method, and it appears to be capable of greater accuracy than is here indicated; for in most cases, and apparently in accordance with Mr. Pemberton's directions, larger quantities of the molybdate were added between each test towards the close of the titration than were necessary; these additions should be made by 0·1 cc. at the most. But the results obtained in the case of No. 261 do not agree closely enough hardly even for technical work; there seemed to be some source of error there which may be revealed by a further examination of the phosphate.*

I am permitted by Dr. S. M. Babcock, now chemist of New York State Experiment Station, to mention in this connection his good success in determining reverted acid by precipitation with magnesia mixture from the ammonium citrate solution, according to Johnson's method, solution of the precipitate in nitric acid, and titration with standard molybdate.

[The yellow phospho-molybdate has frequently been used as a basis of calculation in determining *small* quantities of phosphorus in analyses of iron and its ores. But never, to my knowledge, has it heretofore been successfully employed where large percentages of P_2O_5 were to be determined. Previous to the investigations of Dr. Gibbs, on the phospho-molybdates, many chemists were in doubt as to whether the yellow precipitate, with its extraordinary formula, actually was a definite chemical compound or not. Different analyses of it varied as much as 30 per cent. on the total P_2O_5 contained therein. Eggertz and Finkner showed how the precipitate could be formed so as to vary in per cent. P_2O_5 within moderate limits, and the phosphorus estimations in iron and steel were thereupon based upon the direct weighing of the yellow salt.

It appears to be an impossibility, however, to precipitate the pure yellow salt, with the ratio of MoO_3 to P_2O_5 *exactly* as 24 : 1, when the usual nitric acid solution of the molybdate is employed. Because the length of time during which the solution must stand in the heat, and the large excess of the precipitant required, cause more or less MoO_3 to fall with the precipitate.

It is very evident, therefore, if there is any tendency in the same direction when the *aqueous* molybdate solution is employed, that the volumetric process would be unreliable, and the error a radical one. Happily, however, there is no danger of this; there cannot possibly be an excess of the molybdate in the solution, except the fraction of a cubic centimetre at the very end of the titration. My original experiments, together with the subsequent experience of nearly three years, are corroborated by the above criticism of Prof. Caldwell, and they all go to prove the constancy and reliability of the process.

It may be worth noting, that this is the only known volumetric process of determining phosphoric acid when iron or alumina are present, or when the solution is a nitric acid one.

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* Since the publication of the above, Prof. Caldwell writes: "To what appears in this report I might add that quite a number of additional analyses of the same fertilizers have since been made by my students, and with as good results as they get by any other method. I always use the suction filter described in the paper that you will receive, and which I think Mr. Pemberton will like as an auxiliary to his method."

The only drawback I have found—that of determining with quickness the final point of the reaction—has been very largely overcome by the happy idea of Prof. Caldwell, illustrated in his paper above.

It is evident that this little portable Bunsen filter can be used with advantage in many other volumetric methods of direct precipitation, and would doubtless give a practical nature to a variety of processes otherwise difficult or tedious.

HENRY PEMBERTON, JR.]

SIZE OF DROPS AND THE U. S. DISPENSATORY.

By PROFESSOR CHARLES F. HIMES, PH.D., Carlisle, Pa.

In the recent edition, the 15th, of the U. S. Dispensatory, among other modes of approximate measurement, in the administration of medicines given, is that by drops, and in calling attention to the conditions affecting the size of drops, the statement is made, that "the drops from a full bottle should be less than from one more or less emptied." There is no indication that the statement rests upon direct tests, and it is so decidedly at variance with the results of experiment, that it seems but proper that attention should be called to it. Other conditions remaining the same, drops diminish in size as the bottle is emptied, and to such a degree that any one can satisfy himself of the fact in a few minutes. The circumstance which first directed my attention to the subject will illustrate also the degree of variation in size. It was assigned to a student in the laboratory, as an exercise, to ascertain how far drops might be substituted for more precisely measured quantities of liquids in making comparative determinations for domestic or even commercial purposes. As a preliminary test of the degree of uniformity of results, the hardness of a constant quantity of the same sample of water was destroyed by dropping into it standard soap solution, from the same bottle, and the same portion of the lip. The number of drops of course varied, but, after some skill had been acquired in using the method, in a series of experiments, the number of drops reported as required, indicated regularly increasing hardness for four experiments, then a sudden diminution, succeeded by regular increase. Upon watching the procedure of the student, there seemed to be no condition varying with the same regularity except the amount of liquid in the bottle, and consequent size of the drops; and upon performing the experiments by filling the bottle up to the same mark for each trial, the previous periodicity disappeared, and the uniformity of results was greater than had been anticipated. Subsequent experiments with different bottles, and different liquids, demonstrated that the differences in size of drops occasioned by the variation in the amount of liquid in a bottle were not such as might in all cases be overlooked with prudence in the administration of medicines, and that the method of drops, untrustworthy at best, was rendered much more so from this fact. Upon reference to an older edition of the Dispensatory, on hand at that time, no allusion to the effect upon the size of the drops of the amount of liquid in the bottle was made, and it seemed hardly necessary to call attention to a fact presumably known to any who had employed the method.

Since sending the preceding hastily prepared note upon the size of drops I have taken the opportunity to run over the literature of the subject as given in the *American Journal of Pharmacy*, not then at my command, and am surprised that, with the painstaking character of the investigation of the conditions affecting the size of drops, this one of the degree of fullness of the bottle is practically uninvestigated, and left among the undetermined conditions.

In 1830, Durand* called attention to a series of experiments by Dr. Shuttleworth, and their appreciation by the College of Physicians of London, and gave as the conclusion from experiments of his own, "that the practice of prescribing fluid medicines by drops is altogether objectionable," and that ignorance of the conditions affecting size of drops may lead to serious consequences. After summing up the usual conditions of density of liquid, cohesion of particles, shape of the mouth of the vessel, etc., he remarks, "besides, in every instance, the first drops poured from any vase are always smaller than those subsequently obtained." There is no indication whatever that he, in the most indirect manner, intends to allude to the condition of the bottle as to fullness, but simply to a fact, which the author has not verified, that the *few* drops *first passing* over the lip of the vessel are smaller than the subsequent ones.

In 1858, Bernoulli† gave results of investigations with great accuracy, "keeping in view the nature of the vessel, the temperature, the rapidity of dropping, and other circumstances calculated to affect the weight."

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* *American Journal of Pharmacy*, vol. 1, p. 165.

† *Schweizer. Zeitschr. f. Pharm.*, 1858, pp. 97—100; *Am. Jour. Phar.*, vol. xxxi, p. 441.

In 1860, Proctor* calls attention to the well-established variation in size of drops, with form and size of vessel, with density and viscosity of liquids, "and according to some other of its qualities not yet well understood."

In 1864, Quin, in the *Druggist and Chemist*,† prefaces an abstract of very careful and exhaustive investigations by Guthrie of the conditions affecting the size of drops by a remark upon "the difficulty of obtaining a standard drop, a difficulty which is still more increased by the knowledge that even when the same vessel and liquid are used the differences are almost as great as those already cited."

Parrish, on experimenting with ounce vials of water, found, in seven trials, the drops required for a fluidrachm to vary between thirty-two and sixty-five.

Guthrie investigates most fully "the physical relations existing between the matter on which the drop is formed, the liquid constituting the drop itself, and the medium through which it passes," a condition not clearly expressed before; but, after enumeration of the other usual conditions, as given by Guthrie, Quin remarks: "The condition, however, which has the greatest effect upon the size of the drop is the interval which takes place between the successive drops, and called by Prof. Guthrie the *growth-time*."

The careful experiments by Prof. Guthrie upon the influence of this condition are quoted, with his conclusion that, "on the whole, the law seems to be, the slower the dropping the smaller the drop." This was regarded as a most interesting fact to the pharmacist, as showing "the influence of rate in dispensing drops."

The paper of Prof. Guthrie is highly commended for its exhibition of talents and patience in investigation, and this "enormous and evidently most fruitful field" of investigation commended to him. But although growth-time may in some way be involved in the degree of fullness of the bottle, in not the remotest manner is the latter condition alluded to.

In an editorial of the *American Journal of Pharmacy*, Feb., 1877, vol. 49, differences in size of drops, of from 30 to 100 per cent., from the same vessel, is remarked upon, and the experiments of Durand, before mentioned, are alluded to.

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* *Lon. Pharm. Jour.*, July 2, 1860; *Am. Pharm. Jour.*, vol. xxxii, p. 428.

† *Am. Jour. Phar.*, vol. xxxvi, p. 522.

In 1880, Talbot* gives an account of experiments upon this subject, alludes to those of Durand and Bernouilli, and, in summing up his results, gives the opinion that "the administration of powerful medicines by drops is always dangerous," that "a single bottle is inconstant" as to size of drops, that "cohesion exerts the greatest influence upon the bulk of drops, temperature very little effect, and rapidity of dropping almost none,"—the last conclusion being at variance with that of Guthrie, previously given.

In none of these papers has the condition mentioned and illustrated in my first note, been alluded to.

NOTES ON THE METALLURGY OF NICKEL IN THE UNITED STATES.

By William P. Blake, F. G. S., New Haven, Conn.

[Read at the Boston Meeting of the American Institute of Mining Engineers, Feb., 1883.]

The metallic element Nickel, discovered by Cronstedt the mineralogist, in the year 1751, as a peculiar metal in kupfer-nickel, remained for a long time comparatively unknown in its true characters. It was at first obtained as a secondary or by-product, in the manufacture or extraction of cobalt, being found concentrated in the cobalt speiss left in the pots when smalt or cobalt-blue glass was manufactured. Cobalt at that time was the product chiefly sought, and nickel in its applications was unknown. Since the discovery of the artificial ultra-marine blue, the demand for cobalt has been lessened, while the increasing uses of nickel have made it of first importance, and the conditions are thus reversed.†

But the nickel so produced from the residues was contaminated with copper, iron or arsenic, and in this condition it entered into the composition of the familiar alloy commonly known as German silver, but properly known as nickel silver.

The so-called nickel or nickel bronze was a complex, irregularly constituted alloy, in which less than one per cent. of arsenic was sufficient to greatly modify its physical properties. And it was difficult to free the metal from this element. It may be said that until within a few years, the element nickel, in its true characters and in a comparatively pure condition, was commercially unknown.

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* Am. Jour. Phar., vol. lii, p. 337.

† See Daubrée, *Substances Minerales*, p. 158.

To the scientific chemists, however, its true physical properties early became known, though not without some contradictory and varying results, at first, resulting no doubt from minute differences of composition of their samples according to the nature of the processes employed for the extraction of the metal. Richter found that nickel oxide strongly ignited in an earthen crucible with carbon, gave the metal in a perfectly malleable, ductile condition. It could be hammered cold or hot into plates $\frac{1}{100}$th of an inch in thickness, and could be drawn into wire $\frac{1}{56}$th of an inch in diameter.* Its malleability was found to be diminished by carbon or manganese. On the other hand, Tupputi found that nickel reduced in the presence of carbon in a covered charcoal crucible and under glass, formed more or less nickel-graphite, absorbed a portion of carbon, and was less ductile than zinc. It was brittle when cold, and was as fusible as cast iron (Erdman), while the metal obtained by Richter was difficult of fusion. He also noted that nickel could be welded, but Tourte found that it welded but imperfectly.

Deville cited cobalt and nickel as metals with useful physical properties but little known, such as malleability, ductility, and a tenacity supassing that of iron. He showed that these metals could be worked at a forge with the same facility as iron; that they were susceptible of being employed in the same manner and were less oxidable.†

Inasmuch as nickel first became known commercially in the industrial arts in the form of an alloy, there were no special attempts to produce the metal in a state of extreme purity. The nickel silver of commerce answered all the existing demands, and was of course much easier to make, and cheaper than the pure nickel. It found a large and rapidly extending consumption as a substitute for silver spoons and forks and for silverware generally, especially when the new art of electro-plating was developed by Spencer, Smee, and others. The nickel silver was specially well adapted to receive and hold the deposit of silver, and it is to this day the most desirable alloy for plating.

The use of nickel alloy for small or subsidiary coins next made an increased demand for nickel. Tentative efforts were made by Dr.

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* Cited in Gmelin v. 361.

† Comptes Rendus de l'Academie.

Feuchwanger, in New York, in the year 1837, and he actually issued many small one-cent and three-cent pieces, made of a nickel alloy, the exact composition of which he was careful not to state, but called it "Feuchtwanger's Composition." Switzerland commenced using nickel alloy coins in 1850; the United States in in 1857, though sample coins, one-cent pieces, had been made by Prof. James C. Booth, at Philadelphia in 1853, the prepared alloy containing from 5 of nickel and 95 of copper, to as high as 30 of nickel, and 70 of copper. The alloy adopted by law consisted of 12 of nickel and 88 of copper. The five-cent pieces now in circulation are made of an alloy of 25 parts of nickel and 75 parts of copper. In 1860, Belgium adopted an alloy of the same proportions, for small coins. Other countries have followed, until the use of nickel alloy for small coins may be said to be almost universal in the chief commercial countries. Up to June 30th, 1876, the United States had alone issued of the five-cent nickel to the extent of $6,716,129 in value. Another sudden demand for a larger supply of nickel sprang up when the art of depositing nickel by electricity was perfected. The many and increasing applications of this art need not be here enumerated. It is sufficient to state that at the present time, they constitute a large part of the present consumption of the metal in this country, where the art may be said to have originated in a successful, practical form.

Nickel ore is more generally distributed throughout the mineral-bearing portions of the United States than is generally supposed. It is commonly associated with chrome ores from Canada to Maryland, on the Atlantic side, and equally with the chrome ores of the Pacific slope, notably in Oregon. It is also a common associate of magnetic pyrites in the Archæan rocks, being found in Litchfield county, in Connecticut; in the Highlands of the Hudson, in New York and in New Jersey; and especially at Lancaster Gap, in Pennsylvania, where the chief supply of nickel has been obtained for the United States. This ore yields from 1½ to 2 per cent. of nickel, but is enriched by smelting at the mine into a matte containing 10 per cent. or more of the metal. This locality was worked some thirty years ago by Prof. James C. Booth and others, of Philadelphia, and some nickel alloy was made. Some ten years later Mr. Joseph Wharton purchased the works and established the industry at Camden, N. J., opposite Philadelphia, where it has since been carried forward.

A large portion of the metal produced at these works by Mr. Wharton has been used at the United States mint for the subsidiary small coins, and a considerable amount has been exported. Since the development of nickeling by galvanism, a large part of the product has been put into the form of nickel salts and anodes.

But Mr. Wharton not being content with the production of impure nickel, early commenced experimenting to determine whether nickel could not be produced in a pure and malleable condition, susceptible of being worked in nearly the same manner as iron, and of being applied in the manufacture of various objects requiring strength of material and a material that cannot be easily oxidized. One of his earliest experiments was to take the somewhat spongy mass got by reduction of the oxide of nickel, and after heating it to full redness, work it under a steam-hammer into a bar.

In 1873, Mr. Wharton sent to the Vienna Exhibition a sample of nickel in the form of axles and axle bearings, and at the exhibition in Philadelphia in 1876, he exhibited a remarkable series of objects made of *wrought nickel*, such as bars, rods, a cube, a horse-shoe magnet and magnetic needles of forged nickel. These did not excite the interest to which they were entitled as a remarkable advance in the working of this little-known metal. The exhibit did not cause much comment, and it was not specially described or reported upon, so far as I am aware, except by the judges who reported the exhibit to the Commission as worthy of an award in the following terms: "A fine collection of nickel ores from Lancaster County, Pa., with nickel-matte, metallic nickel in grains and cubes, and manufactured nickel, both cast and wrought; nickel magnets and magnetic needles, cast cobalt, electroplating with nickel and cobalt, and salts and oxides of both these metals; the whole showing a remarkable degree of progress in their metallurgical treatment."*

Some of the same objects formed of wrought nickel, were sent over to Paris two years later, and were exhibited in the American Section in 1878. There, as in Philadelphia, they did not at first excite any surprise, or receive any special attention. Very few persons realized what the objects really were, and that they were very different from *alloys* of nickel. In fact, very few chemists had ever seen *nickel*. Pure nickel was a rarity, a curiosity, just as samples of indium or thallium are to-day.

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*Reports and Awards, Group one, 640, p. 470.

You can then, perhaps, imagine the incredulity of the expert chemists and metallurgists of Europe, when whole ingots and forged bars of metal and numerous finished articles of pure wrought nickel, without alloy, were offered for their inspection. These articles not differing greatly in their appearance from the higher grades of nickel alloys, or from electro-nickeled objects, they passed them without surprise. No previous exhibition had been so rich in exhibits of the use of nickel and in the products from them. The influx of the pure carbonated and oxidized ores from New Caledonia, had greatly stimulated the nickel industry in Europe, and had improved the quality of the alloys of nickel. New companies had been formed to manufacture nickel silver and to produce nickel from these superior ores, at a lower cost than had before been possible. Christofle of Paris had just erected extensive works at St. Denis, and had made a most brilliant display of his products in one of the main avenues of the Exposition. The Vivians of Swansea and other exhibitors had large cases filled with beautiful objects of hollow and solid ware made of nickel silver. Amid these various exhibits of striking *tours de force,* the modest little showcase from the United States with examples of manufactures of *pure wrought nickel,* not alloy, could hardly be expected to excite attention and win the golden award, which was most cheerfully accorded as soon as the fact was demonstrated by analysis that the objects were really of the pure metal. Some of the objects now shown were at that exhibition, and have retained their brilliant polish and lustre unimpaired. These notable advances in the metallurgy of nickel, made with the lean and sulphuretted ores of Lancaster Gap, prepared the way for greater advances.

Dr. Fleitman of Iserlohn, Westphalia, Prussia, has improved and cheapened the operation of refining the nickel and toughening it, and has reduced the liability to the presence of blow-holes in castings by adding to the molten charge, in the pot, when ready to pour, a very small quantity of magnesium. This is immediately decomposed, magnesia is formed, and graphite is separated. It would seem that the magnesium decomposes the occluded carbonic oxide, or reduces it to a minimum. The magnesium must be added with great care, and in small portions, as it unites explosively with the charge. It is stirred in. About one ounce of magnesium is sufficient for 60 pounds of nickel. Three-quarters of an ounce to 54 pounds of metal has been used with success by Mr. Wharton. The nickel from the ore at Lancaster Gap, seems not to require as much as the foreign metal. It is to be noted that complete malleability of nickel was obtained at Wharton's Works in Camden, before Fleitman's invention or process, but this last is more rapid and better than the old method. The metal so treated becomes remarkably tough and malleable, and may be rolled into sheets and drawn into wire. Cast plates can be successfully rolled. The cast plates, such as are made for anodes, after reheating, are rolled down to the desired thickness. It is found that it is a great improvement to the nickel anode plates to roll them down. They dissolve with greater uniformity in the bath. Nickel so treated with magnesium has been rolled into sheets as thin as paper. Expensive works for rolling the metal have been erected by Mr. Wharton at Camden. There is already a train of 40-inch rolls, 18 inches in diameter, with annealing ovens and gas furnaces and their adjuncts, and a 90 horsepower engine. At present this mill as well as the works for producing the metal, and the mine also, are "shut down."

The largest sheet yet rolled at Camden was 72 inches long and 24 inches wide, of pure nickel.

Dr. Fleitman has also succeeded in welding sheet nickel upon iron and upon steel plates, so as to coat them equally on each face with a layer of nickel. The quantity preferred by weight is $\frac{8}{10}$ iron and $\frac{2}{10}$ nickel, one-tenth of nickel being placed on each surface. To secure union the iron or steel must be perfectly flat and clean. A pile is made with outer facings of sheet iron to protect the nickel from scaling. When the whole is heated to the proper degree, it is passed through the rolls. The two metals become so firmly united that they may afterwards be rolled down, two or three together, or separately, to the thinness desired.

The samples exhibited were cut from sheets made at Mr. Wharton's works at Camden. One sample No. 20 gauge, 10 per cent. nickel; one sample No. 22 gauge, 10 per cent. nickel; one sample showing edge of sheet.

These are all examples of nickel upon iron. I also show a thin sheet of pure nickel annealed. The physical properties of the two metals, iron and nickel, are so nearly the same that they work well together. The nickel surface cannot be removed or regained in the scrap and waste except by dissolving out the iron core by dilute sulphuric acid. In the earlier experiments, the ingots or cast plates were beaten under the hammer; this produced a great deal of scale and waste, as with iron, but this is now avoided, partly by the device of a thin covering of sheet iron which is afterwards dissolved off. Dr. Fleitman claims to have produced steel wire similarly coated, and proposes to make nickeled boiler plates.

The applications in the arts of such nickeled iron sheets as I have described, will readily suggest themselves. Up to this time the most direct uses seem to be in making hollow ware, particularly culinary vessels. The manufacture has already begun at Schwerte, by Dr. Fleitman, and a great variety of vessels, such as saucepans and kettles have been turned out, some of them of pure sheet nickel. They are all very beautiful in appearance, resembling highly finished platinum vessels more than ordinary ware. When planished and buffed off, the surface becomes like a mirror, and will answer the purpose of one. The small vessel exhibited is made of nickeled iron, and will show the facility with which the compound sheet metal may be stamped, spun up, and polished. Much larger specimens of ware might be shown.

This ware is believed to be far superior to tinned iron or tinned copper for cooking in. The nickel is not only less liable to corrosion, but is harder, will wear longer, and cannot be melted off by overheating. The ware is lighter and stronger than tin or copper ware; is susceptible of a high polish and is not easily tarnished. It appears to be well adapted to the manufacture of dishes, salvers and covers for the table. The coating of nickel applied by welding is stronger and tougher than that deposited by electrolysis, and appears to be less liable to scale off. The electrically deposited metal is in some cases very brittle, and no doubt contains sufficient hydrogen to essentially modify the physical characters of the coating.

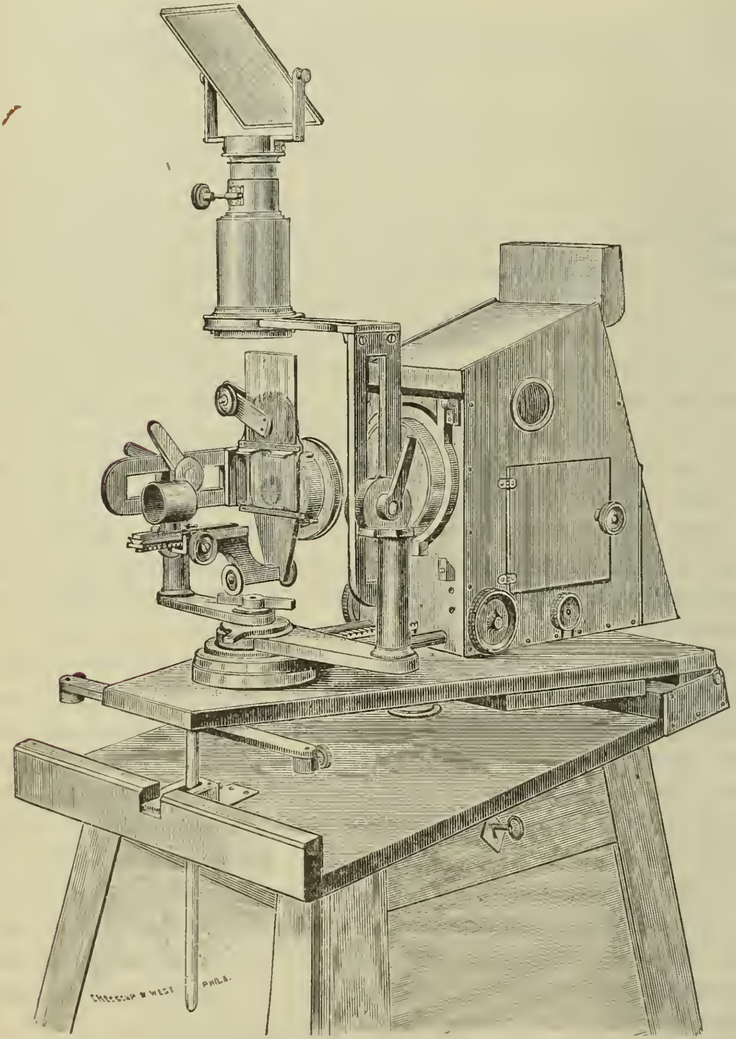
My purpose in this article is chiefly to record some of the most notable advances in the metallurgy of nickel made in the United States, and particularly to direct attention to the production by Mr. Joseph Wharton at his works in Camden, before the year 1876, of *pure nickel* in a malleable state and in considerable quantities, and the manufacture of useful articles from it by forging and working it in the same manner as iron is forged and worked; thus exhibiting for the first time, in the "large way," the true physical characters of this metal, and its adaptation to many purposes in the arts, as had already been partly indicated, in the "small way," by scientific chemists in their laboratories.

I also desire to direct attention to the improved magnesium process of Dr. Fleitman; to the manufacture of nickeled iron and steel in rolled sheets, and to the industries which the possession of pure nickel in commercial quantities renders possible.

THE HOLMAN LANTERN MICROSCOPE.

By John A. Ryder,
Embryologist to the U. S. Fish Commission.

The instrument illustrated was recently made by Mr. Joseph Zentmayer, of Philadelphia, and presented by subscription to the Franklin Institute. It is the invention of Mr. D. S. Holman, Actuary of the Institute, and is not only adapted to show transparent photographs, but may also be converted, in a few minutes, into a projecting microscope, polariscope, megascope, vertical lantern, as well as into a table microscope. The condensors of the lantern are five inches in diameter, and the whole apparatus is constructed in the most substantial way, and every part and accessory is of the best workmanship. The principal and most important feature of the apparatus consists in making the object to be projected when the apparatus is to be used as a microscope, or as a megascope, the centre of all the projecting and illuminating apparatus. The lantern upright which carries the projecting lens or microscope, and the upright which carries the lens and mirror for the vertical lantern and the lantern itself, swing around a common centre which is placed exactly below the centre of the stage on which the object rests. This enables the operator to arrange with the greatest facility the relative positions of each of these parts in any desirable position in respect to the object. This feature it is claimed has never before been accomplished, and makes the lantern more complete, especially as a megascope. The lantern and jet are movable, independently of each other, by means of racks and pinions. By this arrangement the conjugate foci of the condensor may be changed to suit low and high powers and narrow and wide angle objectives, doing away with all secondary condensors and accomplishing these adjustments better and with much greater facility. The raising and lowering of the lantern is effected by a peculiarly constructed clutch, which rigidly holds the instrument in any inclined position. The instrument is packed in a truncated pyramidal box, containing also the accessories, and forming at the same time a firm stand for the lantern, on which it may be rotated when in use. In consideration of the fact that the instrument can be used for such a variety of purposes for lecture illustrations, it cannot be regarded as other than a marked improvement upon a similar class of instruments hitherto used for such purposes. In the illustration and projecting of living forms alone, in conjunction with a number of ingenious devices serving as live cages, Mr. Holman has done a real



Holman Lantern Microscope.

service for the cause of education. While it is perhaps not possible to enter into an elaborate or detailed study of any organic forms of even a moderate degree of complexity, if projected only for a few moments upon a screen, it is nevertheless a fact that the correct likenesses of such creatures, so shown, gives the beholder a far truer appreciation of what the things are of which he reads in books than he might possibly obtain elsewhere, provided the lecturer is able to explain in a lucid manner and unravel the complicated life histories of the living beings of which he displays enlarged images. In these living animal or perhaps plant pictures we have displayed two classes of facts, namely, those of type and those of function. To the trained biologist they call to mind the occult processes of growth and reproduction by which the forms become what we see them to be. This implies that a wide range of data is to be considered; first, there is the development and evolution of the form, together with what this indicates as to its systematic relationship; second, the vital actions displayed involve the consideration of physiological processes, and these again those internal quasi-chemical and physical actions and interactions by means of which the creature is enabled to maintain its existence and individuality. If such problems are not worth elucidating, we may ask what others there are which are worthy of elucidation. The physiologist who solves the problem of the life actions of an amœba or a maggot has put us in a fair way of appreciating those of a man. If, therefore, better and clearer ideas of animal existence can be fostered in young minds by the aid of any optical appliance whatsoever, that appliance should be welcome as an aid in practical objective instruction. No less effective is this instrument in the illustration of many common facts in physical science. The range of its applicability seems indeed to be limited only by the resources, ingenuity and ability of the lecturer.

Electric Navigation.—Sylvanus P. Thomson describes the new electric boat which has lately been tried upon the Thames. The experiments have shown that the electric machinery is both lighter and more compact than steam machinery of a corresponding power, that the noise and the vibrations are largely reduced, and that it completely suppresses all the inconvenience of smoke, which appears inseparable from steam navigation.—*La Nature*, Oct. 21, 1882. C.

Nickel Crucibles.—M. Mèrmet recommends the use of nickel crucibles instead of silver, in chemical manipulations. They are slightly attacked, it is true, by melted potash, but silver itself is not indifferent to this action. They cost at first much less than silver, and moreover they have the great advantage of melting at a higher temperature. It often happens, in fact, that inexperienced chemists melt their silver crucibles in heating them over a gas lamp; such an accident is not to be feared with nickel crucibles.—*Chron. Industr.*, Feb. 25, 1883. C.

Theory of Electromagnetic Machines. — Tresca's experiments with Deprez's machines give, for the first time, the value of the well-known but unexplained loss of work. This loss has been attributed to different causes. Joubert thinks that the following is the most important. All machines with continuous currents are composed of a certain number of elements, such as the strands of the Gramme ring, which, when the machine acts as a receiver, pass from a position in which the potential energy has a maximum value W_0, to another, diametrically opposite, of minimum value W_1. The difference $W_0 - W_1$, represents the electromagnetic work furnished by the strand in passing from the first position to the second. In order that the movement may continue, it is necessary to reverse the direction of the current in the strand, or, in other words, to destroy the electric energy which it possesses, and restore the primitive energy W_0. This operation is repeated twice in each revolution for each strand. It is known, experimentally, that in the receiving machine the change of current must be made before the strand passes the line of the poles. The position of the commutator is given analytically by the condition that the electromagnetic work, $W_0 - W_1$, must be a maximum. Like considerations may be applied to the machine when working as a generator. All the coefficients which enter into the equations can be determined directly. The verification of the theory is, therefore, comparatively easy. It is indirectly confirmed by the values which Tresca has given. The value which they give for the coefficient of self-induction in Deprez's machines is of the same order of magnitude as the observed value. [Chase's discovery that the work of gravitation, at sun's surface, during a half rotation, gives the velocity of light, and Webber's electromagnetic ratio, lend additional interest to this theory.]—*Comptes Rendus*, March 5, 1883. C.

Rainbow Glass.—The soap-bubble colors upon glass are produced by a vapor, which is deposited on the hot glass before it goes into the annealing oven. The vapor comes from a mixture of protochloride of tin, carbonate of baryta, and carbonate of strontian. It is said that the workmen of a Bohemian manufacturer, wishing to celebrate his arrival, kindled some Bengal lights in the annealing furnaces, and the pieces which were in the furnaces all became iridescent. The colors can be removed by hard rubbing. Messrs. Clémandot and Fremy produced a pearly lustre, like that of shells, by means of different chemical agents, chlorhydric acid among others, under pressures of four, five or six atmospheres. They were thus able to imitate the magnificent glasses of antiquity, which have become iridescent through the lapse of time.—*Bull. de la Soc. d' Encour.* C.

Photographing the Solar Corona.—Huggins has succeeded, by the aid of colored glasses and solutions of potassic manganate, in photographing the corona. Using a Newton 3-inch telescope, with a focal distance of 3½ feet, he obtains a very distinct photographic image of the sun, without any perceptible defect. When the exposure is very rapid there can be seen around the sun, under suitable conditions of illumination, the interior corona, which is more regular in form than the exterior corona, and which extends about a quarter of a solar diameter beyond the sun's image. An exposure a little less rapid produces a reversal of the photographic image of the sun; the interior corona is absorbed in the exterior, which appears black, as in a negative proof. If the exposure is a little longer, the reversal is produced both in the solar image and in the corona, but not in those parts of the plate which are affected by the atmospheric light alone. Afterwards the plate represents the corona in white, as in a positive proof, and the atmospheric light in black. Then the straight and curved lines, and the other varied forms which characterize the corona, can be easily traced. Capt. Abney has carefully compared these plates with those which were taken during the last total eclipse. He does not doubt that Huggins is able to photograph the corona at any time, without waiting for eclipses which occur only fifteen times in a century. The new method will enable observers, especially in southern climates and at high elevations, to make this phenomenon, which is one of so great importance in solar research, the subject of daily study.—*Comptes Rendus*, Jan. 2, 1883. C.

A New Food.—According to the *Chemiker Zeitung*, M. Muller has evaporated skimmed milk in a vacuum, so as to obtain a permanent product, which can be preserved for many months in a dry atmosphere, and which has valuable alimentary properties. He thinks that it may be of great use in pastry, and in various kinds of baking, and the best sugar of milk can be made from it. The skimmed milk which is collected in dairies and cheese factories is usually given to animals or wasted in sewage; it contains, however, large quantities of salts, and particles of butter and casseine, which can be utilized by Muller's method.—*Rev. Scientif.*, Jan. 6, 1883. C.

Influence of Fluids upon Sound Waves.—Felix Auerbach publishes the following experimental results: 1. The geometrical lowering of tone, which a fluid produces in a cylindrical glass which it completely fills, diminishes in magnitude with the height of the tone of the empty glass. 2. The arithmetical lowering which a fluid produces in a cylindrical glass of medium register is nearly inversely proportional to the square root of the number of vibrations of the empty glass. 3. The lowering which a fluid produces in a cylindrical glass which it completely fills is not perceptibly dependent upon the height of the glass. 4. The geometrical lowering in cylindrical glasses of different diameters is greater the narrower the glass. 5. The arithmetical lowering is approximately inversely proportional to the square root of the diameter of the glass.—*Ann. der Phys. u. Chem.*, Nov. 15, 1882. C.

Use of Liquefied Gases.—In Krupp's establishment compressed carbonic acid is used for the manufacture of ice and of seltzer water. Dr. Raydt has taken out patents for drawing beer under a pressure which is produced by liquid carbonic acid. Major Witte has provided the steam fire engines of Berlin with pipes for the discharge of compressed carbonic acid into the steam chamber. When the engine starts from the station the boiler is heated; on arriving at the fire the carbonic acid is first employed as a motor, then the gas and the steam work together, and finally steam alone is used. By this arrangement the engine is brought into action four or five minutes sooner than would be otherwise possible. The consumption of the liquid gas is about 8 kilogrammes; twice the amount should be taken, and in two receptacles, to allow for the portion which congeals in cooling—*Rev. Scientif.*, Jan. 6, 1883. C.

Tea Culture in France.—Experiments have been undertaken to acclimatize the tea plant in the department of Loire-Inférieure. Some grafts upon camelia stocks have been subjected in the open air to a temperature of 18° below zero (— ·4°F.). In Sicily, near Messina, similar experiments have been continued for three years; 120 shrubs have been exposed in the open field, through the entire winter, and are all flourishing. The leaves are of as good quality as the Chinese. The shrubs are planted like vines, and yield two crops per annum.—*Les Mondes*, Dec. 2, 1882. C.

Congelation of Solvents.—If A designates the lowering of the point of congelation due to the presence of one part of any soluble substance in 100 parts of the solvent; M, the molecular weight of the dissolved substance; T, the lowering of the point of congelation by a dissolved molecule; F. M. Rault finds that MA = T. From his experiments he derived the following conclusions. Every body, when dissolved in a liquid which is capable of solidification, lowers the point of congelation. In all liquids, the molecular reductions of congelation which are due to different compounds approximate to two values, invariable for each liquid, of which one is double the other. The normal molecular reduction of congelation varies with the nature of the solvent. A molecule of any compound, on being dissolved in 100 molecules of any liquid, lowers the point of congelation by the nearly constant quantity 0°·62 (1·°12 F.)—*Comptes Rendus*, Nov. 27, 1882. C.

Vision of Ultra-violet Rays.—Mascart thinks that the views of de Chardonnet, with respect to the office of the crystalline lens in intercepting the ultra-violet rays, require some qualification. Undoubtedly the humors of the eye absorb many of those rays, but without intercepting them completely, and the retina is so delicate an organ that it may be sensitive to the least radiations which escape entire absorption. By employing a spectroscope of quartz or of Iceland spar he found, in 1869, that ordinary eyes see the ultra-violet spectrum of a grayish lavender color. M. Isambert, who appeared to have a peculiarly sensitive retina, was able to chart the rays of cadmium vapor in the Iceland spar spectrum, at an angular distance from H, seven times as great as the luminous spectrum. The wave length in this region is about 210 millionths of a millimetre, a limit which Mascart has not been able to reach even by direct photography.—*Comptes Rendus*, Feb. 26, 1883. C.

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JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CXVI. AUGUST, 1883. No. 2.

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.

CRANES; A STUDY OF TYPES AND DETAILS.

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[A paper read at the Cleveland Meeting of the American Society of Mechanical Engineers.]

In the study of any special class of machines, it is often conducive to a better understanding of the subject clearly to enumerate the several types or forms in which the machine is used, and also to consider each of its more important details separately, rather than in their combination with other elements of the mechanism. It is proposed in the following pages thus to treat the subject of cranes.

The only English text-books descriptive of cranes are Glynn's, which treats of English practice in crane building as it existed more than thirty years ago, and sundry catalogues published by English dealers in machinery as a means of advertising the products of the various builders of cranes for whom they act as selling agents. The practice represented in the former is now almost obsolete, by reason of the improvements which have been effected, and the latter consist of little but a series of pictures of various cranes, without descriptive text, and with no information as to the details of their construction.

The building of cranes has long been recognized in Europe as one of the most important subjects in the field of mechanical engineering, and cranes of many forms are there seen applied to an almost infinite variety of uses. In America, on the contrary, cranes are but little used or appreciated, in comparison, at least, with the extent of their application in European countries. It is the purpose of this paper to present to American readers a brief classification and description of the most important types of cranes, and a similarly brief study of the more important elements entering into their construction, the object of the latter inquiry being to determine, if possible, the best forms of elements to be adopted.

With a better knowledge of crane construction will surely come a better appreciation of their economy and value as labor-saving machines. In hundreds of mills and workshops heavy material is now moved and handled by manual labor at an expense so much in excess of the cost of doing the same work far more rapidly and conveniently by cranes, that the saving effected by the latter would yield an annual profit of from twenty to fifty per cent. upon their first cost, while in many cases this outlay would be entirely repaid by the economy of one year's use.

CLASSIFICATION OF CRANES.

A *hoist* is a machine for raising and lowering weights. A *crane* is a hoist with the added capacity for moving the load in a lateral or horizontal direction.

All cranes, therefore, are provided with hoisting mechanism, and, in addition, must be capable of moving the load in one or more horizontal directions. This second function is effected in some types of cranes by simply pushing the load, in others by the operation of a distinct mechanism.

Cranes are most clearly classified by reference to their modes of transferring their loads horizontally; and, thus considered, are found to divide themselves into the following groups namely:

1. *Rotary.*—In which the load is revolved around a fixed centre, such as a mast or column.

2. *Rectilinear.*—In which the load is moved in straight lines in one or more directions.

Both types of cranes are subdivided into two general classes as to their movements, namely:

(*A.*) *Fixed.*—When their supporting members are fixed in some permanent location.

(*B.*) *Movable.*—When the crane as a whole can be moved about.

And into four other general classes as to their source of motive power, namely:

(*a*.) *Hand.*—When the motions, either vertical or horizontal, are effected by manual power.

(*b*.) *Power.*—When the motions are effected by power derived from line shafting driven by a stationary engine or other fixed motor.

(*c*.) *Steam.*—When the motive power is derived from a steam engine attached directly to the crane itself and moving with it.

(*d*.) *Hydraulic.*—When the motive power consists of hydraulic pressure obtained from a pump or accumulator, and carried to the crane by pipes.

A further distinction is covered by the term locomotive, which is applied to cranes (usually of the rotary type) which are capable of propelling themselves upon a roadway or track.

Rotary cranes comprise the following principal types:

1. *Swing Cranes.*—In which the central mast is pivoted to the floor and roof of the building, and the load is suspended from a block fixed at the outer end of an arm projecting horizontally from the mast, the only horizontal motion being one of rotation.

2. *Jib Cranes.*—In which the central mast is pivoted to the floor and roof of the building, and the load is suspended from a trolley traveling in and out upon an arm or jib projecting laterally from the mast.

3. *Column Cranes.*—Which consist of a jib crane constructed to revolve around or upon a fixed column forming the support of a building or floor.

4. *Pillar Cranes.*—In which the central column or pillar is entirely supported by a heavy foundation built at its base, and the load is suspended from a boom projecting from the pillar and revolving with it or around it.

5. *Derrick Cranes.*—Which consist of a jib crane for yard use, the upper end or pivot of the mast being held in position by guy-rods or stays, instead of by attachment to a roof or ceiling.

6. *Walking Cranes.*—Which consist of a pillar or jib crane mounted on wheels and arranged to travel by power or by hand upon one or more rails.

7. *Locomotive Cranes.*—Which consist of a pillar crane mounted on wheels, and provided with a steam engine and boiler, the power of

which is available for operating the crane and for propelling it upon its tracks.

Rectilinear Cranes comprise the following principal types:

1. *Bridge Cranes.*—In which a fixed bridge spans an opening, and the load is suspended from a truck or trolley capable of moving across the bridge.

2. *Tram Cranes.*—In which a truck or short bridge, from which the load is suspended, is arranged to travel longitudinally upon a pair of overhead rails, but is without capacity for transverse motion.

3. *Traveling Cranes.*—In which a rectangular space is provided with overhead tracks upon two opposite sides, and is spanned by a bridge arranged to travel longitudinally upon these tracks, the load being suspended from a truck or trolley capable of moving transversely across the bridge, so that the load may be moved to or from any point within the entire rectangle.

4. *Gantries.*—In which an overhead bridge is supported at each end by a frame or trestle extending downward and having wheels in its base to permit of travel upon two longitudinal tracks laid upon the ground so that the entire structure can move endwise upon the latter, and the road, which is suspended from a truck or trolley on the bridge, can be moved transversely across the bridge.

5. *Rotary Bridge Cranes.*—Which combine a rotary with a rectilinear movement and consist of a bridge having one end pivoted to a central pier or post, while the other or outer end travels on a circular overhead track or is supported by a gantry frame traveling upon a circular track upon the ground, the load being suspended from a truck or trolley traveling transversely across the bridge.

The above nomenclature will be adhered to in the following descriptions of crane construction.

HOISTING GEAR.

The most important factor in the economy and convenience of a crane is the mechanism by which the load is lifted and lowered, as it must necessarily come into action every time the crane is used.

In all applications of power, from whatever source derived, it must be remembered that the gearing of a machine can only modify the power applied in one or two ways, namely:

(1.) By reducing its velocity, and proportionally decreasing its force or "pull."

(2) By increasing the velocity, and proportionally decreasing the intensity of the power transmitted.

Under no circumstances, unless the motive force is increased, can power be gained except by a sacrifice of speed, or can speed be increased except by a sacrifice in power. If either or both must be increased without diminishing the other, it can only be accomplished by supplying more motive power.

The function of gearing, then, is to change the force or direction of the power applied. If it is well designed and constructed, this may be done with only a small loss from friction; while, if badly made, the gearing may absorb much power in wasteful friction of its moving parts.

In machinery for hoisting, the "purchase," or conversion of velocity into lifting power is usually effected partly by a multiplication of the ropes or chains of the tackle through which the load is suspended, and partly by gearing within the machine, which latter thus becomes an important feature in crane work. The gearing ordinarily used for this purpose consists either of spur-wheels and pinions, or of worm-wheels and worms, or both combined, and the smoothness and economy of power of the machine depend largely upon the manner in which the gearing is made.

A second feature of prime importance in the hoisting gear of a crane is the mode of sustaining the load, and guarding against its "running down" when the application of the motive power is discontinued. This has heretofore been accomplished, in machines having spur-gearing, by a ratchet-wheel, the pawl of which has to be entirely disengaged to permit lowering to occur, or by a brake which, when on, prevents all motion of the machine, and which requires to be held or thrown off both in hoisting and lowering. In machines having worm-gearing, the end is attained by a construction of their worm-wheels such that the friction between the worm and the wheel is sufficient to prevent the backward rotation of the worm under the pressure of the teeth of the worm-wheel caused by the load, the resistance thus generated sufficing to prevent the running down of the load.

The worm-wheel system is usually safe against accidents, but is not economical of power if the worm-gears are proportioned, as above explained, to hold the load suspended without running backward when the application of power ceases, as is usually the case. The spur-wheel system, on the other hand, is a constant and inevitable source of great danger both to the load and to the operator. With the least carelessness in lowering, the load begins to descend with great velocity, and the mechanism is driven backward with corresponding speed and violence. If not checked, the load then practically falls as if unsupported. If too suddenly checked, violent strain is thrown upon the entire frame of the crane and on its gearing, which latter is thus liable to damage, and even to "stripping" or fracture, in which event the load falls. Where spur-geared cranes are operated by hand, this "running down" of the load involves a reversing or "flying back" of the cranks, which then frequently strike the men before they can escape beyond their reach. Accidents of this kind, resulting in injury to limbs, and even in loss of life, are constantly happening with common cranes, and are reported almost daily in the newspapers.

It is possible, however, so to proportion worm-gearing as to place it almost, if not wholly, upon a parity with spur-gearing in regard to economy of power transmitted, and by the use of cut worm-wheels driven by turned worms or pinions (the teeth of the wheel being formed by means of a chasing hob or cutter), so to construct worm-gearing that it becomes the best and most convenient form of gearing for use in crane mechanism. It is found that gearing thus made will not automatically support the load, and that the latter, if left suspended, will drive the worm-gearing backward; but in this case the descent of the load is quite slow, and no perceptible acceleration takes place, so that the worm-gears thus act as a governor to control the load. By the application of a small brake to the worm-shaft, this tendency is counteracted, and by connecting this brake with the levers which control the motions of the mechanism, the brake is easily made automatic, and thus securely holds the load whenever the crane mechanism is at rest.

In all cranes, except those of small size, provision should be made for one or more changes of speed in hoisting and lowering, so that the speed may be varied according to the load and the nature of the work to be done. Cranes operated by power *may* be so constructed that the maximum load can be lifted at the quickest speed; but they are usually so proportioned that this can be done only at a slow speed. By this plan, much economy of gearing, space, and cost is effected, and the practical efficiency of the crane for all ordinary uses is not impaired. The most perfect construction is one that permits a change of speeds to be made whether the hoisting gear is in motion or at rest, and which sustains the load automatically while a change of speed is making.

The hoisting gear of a crane should therefore attain the following results:

(1.) Such changes in direction and velocity of the power applied as will give the desired motion to the load.

(2.) The accomplishment of this with a minimum loss of power through friction.

(3.) The safety both of the operator and the load under all conditions; to insure which, the load must be always self-sustained and incapable of "running down."

(4.) Capacity for changes of speed and for convenient transition from one of these to another at will, whether the gearing is in motion or at rest, and for the automatic support of the load during the act of changing speeds.

TRAVERSE GEAR.

In this, as in the hoisting gear, good design and construction are essential to economy of power, and frequently to safety against accidents.

In some types of rotary cranes, no traverse mechanism exists, except an arrangement of parts which provides for the rotation of the crane. In others, such as jib and derrick cranes, provision must also be made for moving the truck or trolley horizontally on the jib, and the same provision is required for moving the trolley of bridge and traveling cranes traversely on the bridge. In all such cases, a separate mechanism, distinct from the hoisting-gear, has heretofore been employed, and is still sometimes desirable or convenient. When employed, its parts should be as few and simple as possible, and it should be so far independent of the hoisting-gear as to permit either to be used at any time separately or conjointly. In power cranes provision should be made for accelerating the speed of the trolley travel whenever the nature of the work admits of it. The best possible result is attained when travel of the trolley is effected without varying the vertical position of the load, and without causing useless movement of the hoisting chain or rope over the sheaves through which it supports the load, which movement would involve much additional friction, and cause rapid wear of the chain or rope.

In traveling cranes, a point of great importance is the parallelism of the bridge travel with the longitudinal tracks. Any defect here results in increased resistance to traction, and any considerable error might cause derailment. In traveling cranes, as heretofore built, the use of flanged wheels has been relied upon to prevent derailment, and the propulsion of the bridge has been effected by a transverse shaft extending the whole length of the bridge, and connected by gearing with the truck-wheels supporting each end of the bridge, so that, by revolving the shaft, the truck-wheels would be rotated, and the bridge be thereby propelled, provided the adhesion between the wheels and the rails was sufficient. In some instances, where the adhesion has not been sufficient to prevent slipping, a cast-iron rack has been laid adjacent to the longitudinal tracks, and extending their whole length, and pinions, gearing into this rack, attached to the axles of the truck-wheels, so that propulsion is effected independently of the adhesion of the truck-wheels to the track. If the load were always central on the bridge, and the motive power always applied to this shaft at the centre of its length, this plan would answer well, although it is somewhat clumsy; but in practice the load is constantly varying in position, and the motive power is applied at one end of the long transverse shaft, so that torsion of the shaft induces a considerable variation in the travel of the opposite ends of the bridge. This error is a constantly varying one, according to the portion of the load resting upon each truck, as determined by the position of the trolley, the load being never equally distributed between the two trucks, except when it is exactly in the centre. It follows, therefore, that this system of bridge travel, although operative, is radically defective, and that its use involves a constant loss of power by needless friction, and entails a proportionate amount of wear and tear of rails, wheels, and driving gear.

A better and more simple method of bridge propulsion has lately been introduced, by means of which the longitudinal motions of the bridge are effected by *pulling* each of its ends, simultaneously and at equal speed, in the desired direction. For this purpose, light wire cables are used, which, by a very simple and ingenious arrangement of guide-sheaves, are made to act as a "squaring device," to hold the bridge at all times perpendicular or square to the tracks upon which it travels. By this system, the friction of traction is reduced to a minimum, and the danger of derailment from unequal travel of the opposite ends of the bridge entirely obviated.

From the above facts, it becomes evident that a perfect system of bridge propulsion must hold the bridge always absolutely square with its tracks, and must propel the opposite ends of the bridge in the same direction, at the same time and at the same speed, however unequally the load may be distributed. It is desirable also that, in large cranes at least, provision be made for starting the bridge slowly from a state of rest, and then increasing the speed, and also for varying the speed, while the bridge is in motion.

CHAINS VERSUS ROPES, AND CHAIN-WHEELS VERSUS DRUMS.

In almost every type of crane, the load is primarily carried upon a flexible cord of some kind. This usually consists of rope, either hemp or wire, or of chain. Each of these has distinctive merits and objections.

Ropes have the advantage of being formed of many parts or fibres, so that no splicing or welding is necessary in their manufacture; and they thus have an assured and practically uniform strength throughout their length.

Chains, on the contrary, consist of a series of independent links, each of which is formed from a straight bar, and welded, so that a single imperfect weld injures the whole, the strength of a chain being obviously limited by the strength of its weakest link. By care and good workmanship, however, this danger can be avoided, in which case the chains becomes as safe as the rope, and much more durable.

Where a rope is used, the hoisting-gear must necessarily include a drum or barrel, upon which the rope is wound up when hoisting takes place. Chains may also be thus wound up on a barrel, and this has heretofore been the common practice when chains have been employed in crane construction, and a prominent feature in cranes of large capacity has usually been a proportionately large "winding-barrel" to receive the chain. A chain, however, admits of another mode of construction, which consists in substituting for the wide barrel or drum a pocketed "chain-wheel," consisting of a narrow wheel or sheave, of a width only slightly greater than that of the chain, and having formed upon its periphery a series of indentations or "pockets," exactly corresponding in size and shape with the links of the chain, so that the chain and the pockets fit together accurately, and slipping of the chain upon the chain-wheel becomes impossible. It thus follows that rotation of the chain-wheel causes positive motion of the chain at a speed equal to the circumferential velocity of the wheel, in a manner precisely similar to the motion of a rack driven by a pinion, or of one spur-wheel driven by another.

To be used in this way, it is necessary that the chain should have a constant and uniform "pitch," that is, that all the links should be exactly alike, so that the distance from link to link shall be always the same (just as in spur-gearing the spacing or pitch of the teeth must be uniform), and also that the pitch or spacing of the pockets of the chain-wheel corresponds accurately with the pitch of the chain. If this be done, and if the chain have a cross-section of such area that, when carrying the full load, it is not strained to its elastic limit, or to a degree which will cause any permanent elongation of its links, then a chain may be thus used, in engagement with a pocketed chain-wheel, as well and as safely as on a barrel. Indeed, a properly shaped wheel of this kind is much easier on the chain than a winding-barrel or drum, for the reason that the latter has a cylindrical surface, while the bearing face of the former is not cylindrical but polygonal, the bed or bottom of each pocket being tangential to the radius at its centre, and so presenting a flat surface for the parallel sides of each alternate link to bear upon. When the chain is wrapped upon a cylindrical barrel, on the other hand, the straight sides of every alternate link, being tangential to the surface of the barrel, can each touch it at one point only, the link being unsupported throughout the rest of its length, and the tendency of the strain induced by the load is to bend each of these links to the contour of the barrel. This effect may be easily seen in any chain which has been wrapped, under severe strain, upon a cylindrical barrel, unless the diameter of the barrel be very large. The spiral grooving of a barrel does not remedy this fault, although it affords a much better bearing for the chain than a plain cylinder; which latter is only permissible for small chains and light loads.

For heavy cranes, hemp ropes are rarely used, owing to the size and multiplicity of parts required, and to their rapid wear. They are also inadmissible where liable to be exposed to much heat, as, for instance, in a foundry. Wire ropes are more available, and are often employed; but these also wear rapidly, unless the sheaves and barrels around which they pass are of large diameter, while this requirement, if met, reduces the effective height of hoists and necessitates more parts or gearing to obtain the necessary purchase, and augments the bulkiness of the machine. Either material involves resort to a large winding-barrel or drum.

The usual and best device for large cranes is a well-made chain, and this, when used with pocketed chain-wheels and sheaves, gives the best and most satisfactory results, and leaves nothing to be desired. The adoption of this plan dispenses with winding-barrels, preserves the shape, and therefore the durability, of the links of the chain, and in every way simplifies and compacts the mechanism.

The relative merits of the several systems may now be summed up as follows:

(1.) *As to the Sustaining Cord.*

Hemp Ropes.—Admissible only for small cranes not in frequent use and not exposed to the weather or to heat.

Wire Ropes.—Available under any ordinary conditions, but involving a winding-barrel of large diameter and large sheaves; not economical of space.

Chains.—Possessing, if well made, all advantages and the greatest durability; *common chain,* requiring a winding-drum, but permitting it and the sheaves to be of smaller diameter than with wire rope; *pitch chain,* dispensing with a drum and admitting of the use of a narrow chain-wheel.

(2.) *As to the Winding Device for Hauling In and Paying Out the Rope or Chain.*

Winding-Drums or Barrels.—These must have a diameter and length such as will enable them to receive the whole length of rope or chain to be hauled in by winding it upon their surface in one coil, without overlapping. In large cranes, the load is usually carried upon four, six, or even eight parts of rope or chain, so that the length to be wound up amounts to four, six, or eight times the effective hoist, and the dimensions of the barrel thus become very large. Moreover, this barrel must either be caused to travel longitudinally on its shaft, so that the rope or chain as it leads off shall be always in the centre of the crane and hoisting mechanism (which method of construction involves serious complication and greatly widens the space occupied by the gearing), or the rope or chain, as it uncoils, be permitted to vary in position from one end to the other of the barrel, in which case it is nearly always out of centre, thus inducing objectionable lateral strains and causing greater friction and wear.

Chain-Wheels, with Pockets.—These require a width only slightly greater than a single part of the chain, and a diameter merely sufficient to give the proper engagement with it, so that both dimensions become much smaller than in a winding-barrel, and the total space occupied is but a small fraction of that required for the latter device. The *chain-wheel* is fixed in direct line with the chain, and all lateral strains are avoided, while the flat bearings afforded for the chain by the pockets preserve the shape of the links and protect them from bending strains. The slack chain, after passing over the wheel, falls into a proper receptacle below.

From this analysis of the facts is deducted the proposition that chains, if well made, constitute the best form of flexible cord for sustaining the load in a crane, and that a well-constructed *chain-wheel* (as contra-distinguished from a winding barrel) is the best form of device for hauling in and paying out the chain; and therefore, the best method of crane construction involves the use of these two elements.

A REMARKABLE ERROR IN THE COMMON THEORY OF THE TURBINE WATER WHEEL.

By J. P. Frizell.

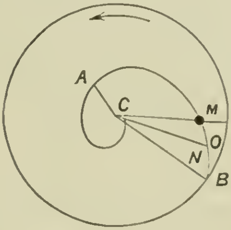
All writers who have attempted a theoretical discussion of the turbine water wheel, have agreed in representing the centrifugal force operating to increase or diminish the discharge of the wheel, by a certain head. The difference, namely, between the head due the rotatory velocity of the wheel at the point where the water enters the wheel, and the head due the rotatory velocity of the wheel at the point where the water leaves the wheel. Among those who have done so to my certain knowledge are Weisbach, Redtenbacher, Rankine, Morin, and Bresse.

To all these philosophers the very careful and complete experiments of Mr. Francis on turbine wheels have been accessible for the last thirty years; giving them, had they so desired, abundant means of comparing their theories with facts. They appear to have ignored these experiments entirely, and to have contented themselves with exhibiting the results of mathematical reasoning. Even in the late valuable and carefully considered treatise of Weisbach, no attempt is made to reconcile his conclusions with the results of these experiments or to explain the discrepancies that must have been known to exist.

To the engineer who attempts to compare theoretical results with those of experiment, nothing becomes apparent sooner than that the above-mentioned principle wholly fails to represent the action of centrifugal force. Mr. Francis, in his "Hydraulic Experiments," expresses the opinion that centrifugal force plays a less important part in the turbine wheel than is assigned to it by mathematicians, though he does not attempt any inquiry into the foundation of the formula by which that force is represented; being probably, like many others, content to regard it as one of those scientific truths which are only true on paper but not true in practice; as a principle which water ought, in deference to eminent authority, to observe, but which its habitual wilfulness and perversity lead it to disregard.

It is always worth while when we meet with a principle, so called, which does not represent facts, to inquire carefully whether it be well founded in theory.

The principle in question is demonstrated by Weisbach in "Mechanics of Engineering, etc." Coxe's translation, p. 610, and more concisely in the introduction to his later work "Hydraulics and Hydraulic Motors," by Prof. DuBois. I reproduce the latter, though both are essentially the same, and this may be regarded as a type of the methods by which the principle is supposed to be demonstrated.



"If the path $C\,A\,B$, in which a body moves, is not at rest, but turning about an axis C, it imparts to the body a centrifugal force P, by reason of which the body either performs work or work is performed upon it, according as it departs from or approaches the axis of rotation C. Let M be the mass of the body, ω the constant angular velocity with which the path turns about C, and let r denote the variable distance $C\,M$ of the body which is moving in the path $C\,A\,B$. We have the centrifugal force of the body (Art. 13) $P = \omega^2\,M\,r$, and for the work done by this force while the body describes an element

$M\,O$ of its path, and hence, while the radius $C\,M = r$ is increased by an amount $N\,O = d\,r$,

$$d\,W = \omega^2\,M\,r\,d\,r.$$

Hence for the whole work

$$W = \frac{\omega^2\,M\,r^2}{2}.$$

Now the velocity of rotation at the distance r is $v = w\,r$, and therefore

$$W = \frac{M\,v^2}{2} = \frac{v^2}{2g}\,G.$$

When we substitute instead of the mass M, the weight $G = M\,g$.

If the body begins its motion, not at C, but at any other point, A, at a distance r_1 from C, where the velocity of rotation is $v_1 = \omega\,r_1$, we have for the work done, while passing from A to M,

$$W = \tfrac{1}{2}\omega^2\,M\,r^2 - \tfrac{1}{2}\omega^2\,M\,r_1{}^2 = \tfrac{1}{2}\omega^2\,M\,(r^2 - r_1{}^2) = \tfrac{1}{2}M\,(v^2 - v_1{}^2)$$
$$= \frac{(v^2 - v_1{}^2)}{2g}\,G.$$

If, then, a body moves in a rigid path or groove which revolves about a fixed axis, the vis viva of the body is increased or diminished by the product of the mass (M) and the difference of the squares of the velocities (v^2 and $v_1{}^2$) at the two ends (A and M) of the path, or by the product of the weight (G) and the heights

$$\left(\frac{v^2}{2g} \text{ and } \frac{v_1{}^2}{2g}\right)$$

due to these velocities. The increase takes place when the motion is from within outward, and the decrease when the motion is from without inward."

Now who can fail to perceive that this demonstration is entirely erroneous, assuming as it does that ω represents the angular velocity of the body M. In other words, that this body has the same angular velocity as the revolving disc. The body M has a motion along the path $C\,A\,B$ independent of its rotatory motion imparted by the disc. This movement is partly angular and partly radial. The angular element of this motion must be added to or subtracted from the angular motion of the disc to find the true angular velocity of the body M on which the centrifugal force depends. This would lead to a very complicated expression for the centrifugal force, involving the equation of the path in which the body moves.

The above expressions would be true if the body M had merely a radial movement on the revolving disc, but are entirely erroneous as soon as an angular element is added to that movement. How entirely a formula deduced from such assumptions must fail to represent the action of centrifugal force in a turbine wheel will appear from this consideration. All the above-mentioned writers prescribe as a condition of efficiency that the water at its exit from the wheel should have the same velocity as the latter, in the opposite direction. In other words, that the angular velocity of the water at that point must be null, while a moment's reflection will show that their formula for the centrifugal force can only be true upon the assumption that the water has, here as well as elsewhere, the full angular velocity of the wheel.

I append the following example of the application of this formula. In Mr. Francis's experiments of 1851 upon a Fourneyron Turbine, he measured the discharge and useful effect at all velocities, from the condition in which the wheel was held fast by the brake, to that in which it ran entirely free. In the table "Hyd. Exp.," p. 33, the discharges are all reduced to a uniform fall of 13 feet. It by no means follows, however, that the variations in the discharge, under these circumstances, are wholly due to changes in the centrifugal force.

As the velocity increases from zero, there is a progressive change in the resultant direction of the water entering the wheel, and it comes more and more into coincidence with the direction in which the water leaves the guides. There is a progressively diminishing loss of head due to abrupt change of direction. Presumably, these two directions coincide, and the loss of head ceases, at the velocity corresponding to the maximum efficiency of the wheel. Between these two limits of velocity, therefore, viz., *O*, and the velocity of maximum efficiency, we should expect the discharge to increase faster than is called for by the formula for centrifugal force. The results of experiments show nothing of this kind.

From the point of maximum efficiency to the point where the wheel runs free, there is an increasing deviation between the direction in which the water enters the wheel and that in which it leaves the guides, and consequently, an increasing loss of head. Between these latter limits, therefore, we might expect the increase of discharge to be less than that called for by the formula for centrifugal force. Between the limits O and wheel running free, we might expect these two causes of discrepancy to neutralize each other, and the formula for centrifugal force to represent the total increase of discharge between these limits better than between any other limits.

The velocity of the wheel, running free, was expt. 23. Internal circumference 37·766 feet per sec.

$$\text{Ext. circum. } 37{\cdot}766 \times \frac{8{\cdot}292}{6{\cdot}75} = 46{\cdot}393 \text{ ft. per sec.}$$

The difference between the heights due these velocities is

$$\frac{\overline{46{\cdot}393}^2 - \overline{37{\cdot}766}^2}{2g} = 11{\cdot}288.$$

The discharge of the wheel, standing still, under a head of 13 feet was (Exp. 43) 136·725 cubic feet per sec. According to the theorem under consideration, the centrifugal force should have the same effect in increasing the discharge as an addition of 11·288 feet to the head. The discharge, therefore, should be

$$136{\cdot}725 \sqrt{\frac{24{\cdot}288}{13}} = 186{\cdot}88 \text{ cubic feet per sec.}$$

The actual discharge in Expt. 23 was 165·37 cubic feet per sec.

Induced Currents in Reciprocal Movements.—In an article published by du Moncel, on Dec. 16, 1882, upon the effects produced in the Griscom motor, he showed that when one of the poles of a permanent magnet is moved before a straight electro-magnet there are three successive induced currents: 1. The one resulting from the approach of the magnet, which is inverse and momentary. 2. Another, which is manifested during the whole passage of the magnet before the magnetic nucleus, and which is indirect. 3. A third, resulting from the removal of the magnet, which is momentary and which, although in the same direction as the first, corresponds to a direct current, because the inductive current is then exerted on an opposite extremity of the magnetic nucleus. Of these three currents only one has the same energy at the different points of the magnetic path. It is the one which corresponds to the passage of the magnet from one end to the other of the nucleus, and it belongs to the category of currents which du Moncel has called currents of polar interversions, and which he is now investigating.—*La Lum. Elec.*, Jan. 27, 1883. C.

BÉTON IN COMBINATION WITH IRON AS A BUILDING MATERIAL.

By W. E. Ward, Port Chester, N. Y.

[A paper read at the Cleveland meeting of the American Society of Mechanical Engineers.]

If society is indebted to the restless spirit of progress for most of its modern comforts and conveniences, it certainly is not yet a debtor for any methods which successfully guarantee immunity against calamities from fire. While other departments of industry have received the benefits of improvement, the continuous and persistent use of combustible material for exposed portions of buildings has limited the intrinsic elements of the art of building construction, and confined improvements only to matters of design.

Incombustible materials are easily obtained, and much better adapted to the purpose for every apparent reason. Doubtless the question of increased cost, both in money and in time required for more thorough construction, may be in a measure responsible for the tardiness in adopting safer methods, and, in addition to greater expenditure, there may have been a want of confidence in the fire-proof methods which have been offered to the public for adoption. The importance of this question induced the writer, in 1871 and 1872, to make some experiments in a new and special direction, for the purpose of ascertaining whether a practically fire-proof building could be designed and constructed, at a comparatively moderate cost.

The incident which led the writer to the invention of iron with béton occurred in England in 1867, when his attention was called to the difficulties of some laborers on a quay, trying to remove cement from their tools. The adhesion of the cement to the iron was so firm that the cleavage generally appeared in the cement rather than between the cement and the iron.

The line of experiments which followed were confined exclusively to working up the reciprocal value of béton, in combination with iron, in the construction of beams which were designed for supporting floors and roofs made of the same material. In this particular, the facts were conclusively developed beyond question, that the utility of both iron and béton could be greatly increased for building purposes, through a properly-adjusted combination of their special physical qualities, and very much greater efficiency be reached through their combination than could possibly be realized by the exclusive use of either material, separately, in the same or in equal quantity.

Experience had long ago proved, that, uprotected iron, associated with combustible materials, is altogether unreliable for building purposes when exposed to a severe fire test; but it has been demonstrated that, if iron is well protected by a heavy clothing of béton, its integrity can be safely depended upon under almost any emergency.

When all doubts were removed concerning the reliability of the several combinations of materials required in the construction, a building, embracing the following radical, new features, was erected, for dwelling purposes, near Port Chester, N. Y. Not only the external and internal walls, cornices and towers of the building were constructed of béton, but all of the beams, floors, and roofs were exclusively made of béton, re-inforced with light iron beams and rods.

Furthermore, all the closets, stairs, balconies, and porticos, with their supporting columns, were moulded from the same material. The only wood in the whole structure being window-sashes and doors, with their frames, mop-boards, and the stair rails; thus excluding everything of a combustible nature from the main construction.

Béton can be used in any form of construction, and is able to serve the requirements of any architectural or decorative effects. All the exterior portions of this house, which are more or less ornamental in their functions, were made of béton in place during the progress of the work. In the interior of the house, the cornices, stiles, and panels of the ceilings are formed of béton, and covered with the hard finish usual in such work. There appears to be no limit to the reproduction in béton of any form used in stone masonry or in stucco. The proportions of material composing the béton for the work varied in strength to meet the requirements of the different parts of the structure: the heavy walls needing the least proportion of cement, while the beams, floors, and roofs required a much larger proportion. Only the best quality of Portland cement, clean beach sand, and crushed blue-stone were used in combination with iron for constructing the building.

The proportions of cement used for the heavy wall work were one part of cement to four parts of sand and fine gravel, thoroughly mixed dry, and dampened with only sufficient water to give it the consistency of well-tempered moulding sand.

A finely crushed and screened, hard, blue lime-stone was found to be better adapted for use in combination with the béton than a coarse sized stone filling, because small sized stones pack closer than large ones, thereby realizing a proportional saving in cement. The tests made to ascertain the comparative transverse strength of different compositions proved that the bond was stronger in béton made with small stone. In breaking test sections made of béton in the form of bricks, the fracture of those filled with small stone was almost invariably across the stone lying in the line of fracture, while the fracture of the test bricks made with a filling of stone three or four times larger, showed a frequent tearing away from the bond between the béton and the larger stone filling, the composition of the béton being the same in both cases.

The proportions of cement and coarse beach sand and gravel, used in re-inforcing iron beams for floors and roof supports, were one part of cement to two parts of sand and gravel. The size of the iron beam, selected for an experimental test, was a four-inch I beam of lightest pattern, twelve feet long, weighing thirty pounds to the yard, and its safety load was limited to eleven hundred and fifty pounds. A plank mould was made the length of the iron beam, twelve inches deep by five inches wide, in the bottom of which a layer of béton was first moderately tamped down to an inch in thickness; then the iron beam was laid on the course at equal distances from each side of the mould, and settled down on the surface of the course of béton to a good bearing. This brought the top surface of the beam seven inches below the top of the mould. The work of filling and tamping the courses was then continued until the mould was filled.

The reason for placing the iron beam so near the bottom of the mould, was to utilize its tensile quality for resisting the strain below the neutral axis when this composite beam was exposed to heavy loads, while the béton above this line was relied on for resisting compression from load strain. The béton became thoroughly hardened in about thirty days, when the following tests of transverse strength were made. It was placed upon suitable supports, with a bearing of three inches at each end. A lever was adjusted so as to bring the testing load on a knife-edge bearing at the centre of the beam. Weight was then applied to the long end of the lever, until the stress on the centre of the beam reached nine thousand five hundred pounds. Under this load there was a deflection at the centre of the beam of seven-sixteenths of an inch, but not a sign of rupture appeared at any point.

The load was then removed, and the beam returned to the original line it occupied before the test, showing that the combination possesses the essential quality of elasticity in addition to the enormous increase of capacity to resist strain over that which was possible for either material to sustain if used separately, and in the same quantity.

It is suggested that for future construction that an inverted ⊥ beam would furnish a more preferable distribution of iron in the composite beams than the I beams which were used.

The result of this experiment demonstrated the reliability of the composite beam of iron and béton, and showed that the adhesion of the cement to the iron could be relied on under heavy strains; and warranted the adoption of béton reinforced with small rods for the floors and roofs.

The beams for supporting the floors throughout the house were placed at such convenient distances apart as to insure perfect safety to the floors, and, at the same time, affording ample opportunities for producing the best effects in deep, paneled ceilings.

The beams were all moulded in position, where they belonged, both for the floors and roofs, and after the same method that the experimental beam was made. The iron beams varied in width and weight per yard in accordance with their length and the prospective load; the largest being nineteen feet long by seven inches wide. When the combination beams were completed and ready for the floors and roofs, heavy planks were firmly placed in position and securely supported between the beams; the upper surface of these plank foundations being adjusted on a level with the top surface of the moulded beams. These planks served as the bottom of the floor moulds, and after the béton comprising the floor was hardened, they were removed.

Channel ways had been moulded in the walls, on a line with the top of the beams, for the purpose of supporting the outer edges of the floors.

Before the floors and roofs were laid, care was taken to cover all the supporting surfaces with paper, to prevent the adhesion of floor and roof sections to their supports. This precaution was necessary, to permit the movement of the floors and roofs that would unavoidably take place under varying temperatures and loads.

A part of the experimental system contemplated an attempt to warm the house by passing currents of heated air between the floors and ceilings, and up through flues, made in close proximity to each other, for that purpose, in the interior walls of the building, and it was necessary to core out a liberal area of lateral openings through the upper portion of the beams, in order to permit a free circulation of heated air. The ceilings rested upon flanges projecting from the lower portion of the beams.

Instead of using sand and gravel, or both, in combination with cement, for floor and roof construction, the preliminary experiments that proved the superior value of broken blue stone for massive work, led to the adoption of washed, fine screenings from the same material for the floors and roofs, because its greater angularity than gravel insured a stronger bond in the work than could be realized by using sand and gravel.

The proportions of materials used for this purpose were: one part of Portland cement to two parts of the fine stone screenings. The preparations being completed for laying down the floors, a thin course of the béton was first put on, and evenly tamped down, to about an inch in thickness, over the whole space intended to be covered. Then rods of iron, five-sixteenths of an inch in diameter, were placed both longitudinally and laterally, at a uniform distance of eight inches apart, over the whole surface. Then, on this, a final layer of two inches in thickness was carefully tamped down. In about eight hours the béton was hardened sufficiently to allow the application of the top surface, which was floated down with a half-inch coat of cement and fine beach sand mortar, made of equal parts of each. This completed the final finish, and made the whole thickness of the work three and a half inches. It will be observed that for the same reason as in beam construction, and, as before explained, the iron rods for reinforcing were placed near the bottom of the work, so as to resist the tensional stresses due to the load, while that due to compression in the upper portion would be sustained by the béton alone. In this manner, and by this process, over thirteen thousand square feet of flooring and roofing were constructed to fill the requirements of the building.

The only test of any consequence upon the combined strength of the floors and beams together was made on a section of the widest floor in the house, where the beams are eighteen feet span and six feet between centres. Casks of plaster were placed upon the floor over the beam, forming a triangular load of thirty tons, which was sustained without any injury to the floor, or measurable permanent deflection. The dimensions of the beam that sustained this load were seven by sixteen inches, and eighteen feet span, reinforced in its lower portion with a seven-inch I beam, weighing fifty-five pounds to the yard.

This test indicates that, in addition to its admitted fire-resisting qualities, the reinforced system of construction challenges comparison with other methods of building in matters of strength and of cost, whether for buildings requiring long or short floor spans.

Experimental tests were made with several partition walls, to ascertain how thin it would be advisable to construct them for light walls where the load was small. The result of the experiments showed that the resistance of partitions eight feet in height, made of béton two and a half inches thick, and reinforced with one-quarter inch iron rods, was equal to brick walls eight feet high, and eight inches in thickness.

It is the opinion of the writer that for the great majority of houses required for dwelling purposes, a system of thin reinforced double walls, with a space of from six to ten inches between them, and reinforced cross connections every two or three feet apart, to unite the outer and inner walls firmly together, could be built up to thirty or forty feet in height, at a cost not exceeding that of first-class brick work.

Besides an equal economy in the construction, such double walls would be an incomparably better defense against stormy weather than the best quality of brick work, because the absorptive capacity of béton is so much less than that of brick.

Thus, all things considered, the thin double-wall system commends itself as containing the main, desirable qualities, essential to the outer and inner wall construction of dwelling houses, embracing, as it would, a sure protection against both fire and dampness, and the means for thorough ventilation. Besides the special fitness of the reinforcing system for floors, roofs, beams, and thin walls, it is an interesting question whether the same system may not be also applicable, and advantageously extended to a more general use in many engineering requirements; especially in situations where immense weights must be sustained, and where iron construction alone is difficult of application, notably in such an important work as the Hudson River Tunnel, where its tubular form is constructed with an outer cylindrical shell of flue iron, and lined inside with heavy brick mason work: much of this tunnel rests upon a treacherous bed of silt, and might be made absolutely safe from a rupture caused by settlement, induced by vibrations resulting from railroad traffic in addition to its own weight, by adding to a thin brick lining a strong béton about sixteen or eighteen inches thick, and work in it three or four courses of iron bars, of suitable size, laid longitudinally and in sufficient quantity to bear any amount of strain that settlement or any other cause might bring upon it. Rings of flat bar iron, interspersed in the béton lining, a few feet apart, would further add to its security.

Although the writer has no personal knowledge of the methods which are to be used in filling the interior of the Statue of Liberty, to be erected on Bedloe's Island, New York Harbor, he is of the opinion that a filling of béton, reinforced with iron, furnishes the best method of increasing the stability of that colossal statue.

The reinforced béton system has also been employed with admirable results in heavy foundations for stationary engines. The writer, three years ago, mounted a two-hundred-and-fifty-horse-power, tandem, compound engine, of very heavy pattern, on a reinforced béton bed, twenty-three feet long, five feet wide, and seven feet deep. It is apparently as firm and hard as a single mass of granite of those dimensions. The outboard bearing of the main shaft is also mounted on a single block of the same kind of construction. The cost of these foundations was less than the estimate made for the same in first-class brick or stone mason work.

It has also been used for lining a reservoir of 96,000 gallons capacity, which was blasted into a ledge.

Another great advantage realized in reinforcing béton with iron, is that the iron overcomes its tendency to check in hardening, within useful limits, however large the surface may be if the distribution of the iron through the work is made with ordinary good judgment. This is demonstrated in the instance of entire freedom from shrinkage checks in the single section of béton flooring laid in the drawing-room of the house under consideration. Its dimensions are eighteen by thirty-six feet, three and a half inches thick, and there is no trace of a check throughout its whole extent. After a period of eight years since it was laid down, and six years of that time it has been, during winters, more or less subjected to unequal strains from expansion and contraction, caused by its exposure to unequal temperatures, while employed as a transmitting medium of heat for warming the room. The method of heating the house is as follows:

In the centre of the cellar is a heating chamber, measuring eleven by sixteen feet, and eight feet in height. Within this chamber is placed an ordinary cast-iron heater, of a capacity for burning about three hundred and fifty pounds of coal per day. Openings were made, about twelve inches apart, all around the top of the surrounding walls of the chamber, leading outwardly to the spaces between the first floors and the cellar ceilings, and also up through the flues within the interior walls which communicate with the spaces between the second-story floors and ceilings beneath them. Vertical iron pipes, of suitable size are located so as to connect the open spaces between the cellar ceilings and first floor, with a large, closed trunk or passage-way, which extends nearly all around the inside of the main wall foundation, under the cellar floor, and finally terminates in a large flue, which leads directly under and into the heating-chamber.

This comprises about the whole system of arrangements in the construction for warming the house with heat radiated from the floors and interior walls.

Its mode of operation simply consists in the body of warmed air passing from the heating-chamber upward, through the walls and under the floors, and in its passage giving up its surplus heat to the surfaces of these flues. As the air becomes reduced in temperature, it naturally descends back through the pipe and trunk passage-ways, provided for its return to the heating-chamber, where it is again recharged with heat. It will readily be seen, that, by this method, a continuous circulation will be maintained with the same quantity of air; and furthermore, that the velocity of the current will vary with the difference of temperature of the air when leaving the heating-chamber and when re-entering the heating-chamber.

By this system, there are about fifty-five thousand cubic feet of the interior of the house heated by radiation, through about thirty-five hundred square feet of floor and wall surfaces, and the capacity of the heating-chamber is fourteen hundred cubic feet, so there is one cubic foot of heated air to forty cubic feet in the house.

The temperature of the air in the heating-chamber averages, in very cold weather, one hundred and seventy degrees, and after delivering its surplus heat to the floors and interior walls, its temperature registers fifty-eight degrees in the flue where it re-inters the heating-chamber for reheating; showing that one hundred and twelve degrees of heat had been given up and utilized for warming purposes. With ordinary care in managing the furnace, a temperature of sixty-eight degrees can be uniformly maintained on the first floor, and from sixty to sixty-two degrees on the second floor, with a consumption of about three hundred and twenty-five pounds of anthracite coal per day in the furnace.

The temperature, produced by this system of heating, is free from the objectionable extreme variations so common with other modes of heating. The walls and floor form such large heating surfaces that the temperature is uniform in all portions of the rooms, while the air is not vitiated by escaping gases or heated dust, as is universally the case where furnaces or steam pipes are used for heating.

It is not claimed that its economic results per pound of coal are greater than that which is claimed for the steam or hot water systems, but if the latter were required to make as liberal a provision for the renewal of fresh air in the interest of an equally good ventilation, the percentage of useful results per pound of coal from steam or hot water would average no higher than the former.

The rain-water falling upon the roof passes through two six-inch iron pipes which are set in the wall, extend across the cellar, and reach into a béton tank in the rear tower, and holding 5,000 gallons, whose water level is thirty inches below the level of the roof. This inverted siphon also forms a distributing system to the various points of consumption in the house, through short branch pipes connected to these mains.

There are also two other tanks made of béton, and holding 3,000 gallons, situated under the main tank; one of these sustains a head of over twenty feet of water, and has never given any indications of leakage.

In regard to the important factor of cost involved in this system of béton construction, its average for beams, floors and roofs, including the supporting platforms for laying them down was a fraction over sixty cents per square foot. This cost also includes the reinforcing iron beams and rods. The cost of the heavy wall work, not including cornices, was about twenty-four cents per cubic foot which includes the cost of plank moulds, required for building up the walls. The advantages that most favored these economical results were cheap material and cheap labor.

The bulk of the material required for the work abounds in inexhaustible quantities, and is always maintainable at moderate cost. The essential skill required, consists in a simple knowledge of the right proportions of material, and of its proper manipulation, both of which can be acquired in a half-day's practice. The most inexperienced laborers can do all the work of the most elaborate béton construction, excepting only the surface finishing, and this, with all the other work can be superintended by one competent, experienced builder.

Along with the foregoing data, it may be well to include an interesting feature of some experiments that were made to test the heat-enduring qualities of béton. A number of large test bricks were made of the same proportion of materials that were used in the construction of the walls, and in subjecting them to different intensities of heat to see how much they could withstand before breaking up; there was no perceptible difference observed in the tendency to fracture whether the bricks were exposed to a gradual or rapid heating. Not one of them broke when subjected to a white heat. Several were heated to a bright red heat, and then plunged into a bath of cold water. They withstood this test without showing a decidedly damaging fracture, and one of the bricks was exposed to an alternate heating and cooling, three times before breaking up.

These results were a surprise, and they suggested the advantage of such a material for the walls of buildings, as a sure defence against uncontrollable conflagrations. The facts that appear to be established by this line of experiments are:

First.—That a system of iron beams reinforced with béton can be made to sustain weights many times greater than the iron beams alone can withstand without reinforcing.

Second.—That floors and roofs can be economically made of béton reinforced with iron rods, capable of sustaining heavier loads, with a less number of supporting beams, than any other system of flooring and roofing now in use, *at equal cost.*

Third.—That the system of reinforced beams and floors affords advantages for a more perfect system of heating buildings uniformly than by the steam or hot water systems.

Fourth.—That the sanitary requirements of complete ventilation are plainly within the reach of this system of construction.

Fifth, and finally.—That it affords a perfect defense against the interior destruction of buildings by fire.

The intrinsic worth of béton construction appears most valuable in furnishing the elements of fireproof construction; and thus inaugurating a reformation in the prevailing system of building based on the principle that safety from loss by fire can be more economically realized through reformation than by exclusive dependence on insurance to indemnify for losses by fire. The amount of capital destroyed by such losses appears almost fabulous, and has been estimated by insurance authorities to be over one hundred million dollars annually in this country. This enormous amount takes no cognizance of the losses due to the disturbance of business relations, and to labor by such enforced interruptions of industry, but the sum of the losses accounted for seems to be enough to awaken an interest in the discovery of some effective remedy for reducing their magnitude.

Yet, if the remedy is only to be found in building more thoroughly, its adoption may remain doubtful so long as the hazardous way of building, and the rates for insuring hazardous property occupy their present relations to each other. Such radical departures from conservative ideas of building as are herein described must necessarily find a slow recognition, and reach public favor like any other innovation—through small and gradual beginnings—and wait until their their merits grow to be regarded as a public necessity.

But, however destructive to the material wealth of the country may be the vast losses of property by fire, they sink completely out of view when compared with the terrible sacrifices of human life that are constantly resulting from unsafe building construction.

Against this fearful consequence of it, humanity can reasonably protest, and claim, for the sake of human welfare, that such structures as hotels, theatres, public schools, and all other places of public resort shall be made invulnerable to the assaults and horrors of fire catastrophies.

In conclusion, it is to be hoped that these experiments may shed enough additional light on the fireproof building question to make the way easy for reducing reinforced béton construction to a system, that will deserve public confidence, and ultimately lead to its common adoption.

THE GRINDSTONE.

By J. E. Mitchell.

[Abstract of remarks made at the stated meeting of the Franklin Institute, June 20, 1883.]

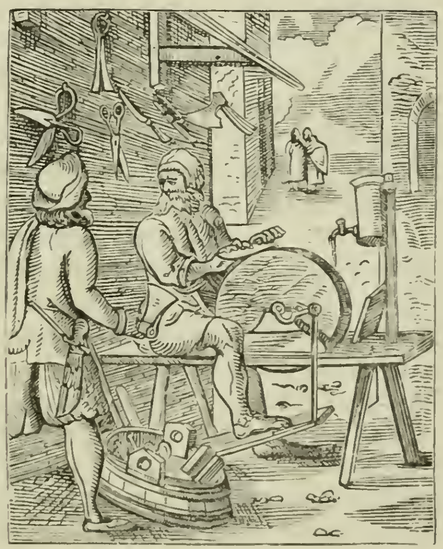
I have nothing new to say about the grindstone; it is the same homely article it was over three hundred years ago, but the application of it has been greatly improved and its uses largely increased, and it now plays a most important part in our machine shops and manufactories, as without its use it would be almost impossible to carry on these works. The Baldwin Locomotive Works consider them of sufficient importance to keep seven Newcastle grindstones, of two tons weight each, constantly at work for grinding off the rough iron work of locomotives preparatory to painting or polishing, and for this purpose they could scarcely be dispensed with, besides running a considerable number of smaller stones for sharpening the various tools for turning and cutting metals.

Grindstones are also used for grinding off the faces of cast-iron pullies, by running the pulley rapidly in one direction and bringing the face of it in contact with a grindstone (kept well supplied with water) running in an opposite direction. This renders the pullies perfectly true, and does the work more rapidly than turning them off in a lathe. A very hard, sharp grit Newcastle stone is found to be best adapted to resist the necessary pressure.

A column was thrown on the screen representing thirteen specimens of the principal American and foreign grindstones, the thickness of the grindstone when in actual use being represented in the column. This has been prepared as one of a series of similar columns intended to represent all the grindstones known both here and in the Old World. They are being prepared by the speaker under the direction of Professor Baird, Secretary of the Smithsonian Institution, and are to be placed in the National Museum in Washington. They will be arranged as a colonnade or court, within which will be placed glass cases containing all the known forms of sharpening stones.

Fragments of every specimen represented will be mounted on glass slides, and ground thin enough to represent the shape, etc., of the particles when placed in a microscope. This will enable the operator to form a correct idea of the cutting properties of the various forms of sandstones which are used as grindstones. Over twenty-five hundred of such specimens of the various sorts of building stones have been prepared, which are now on exhibition in the National Museum, a few of which, through the kindness of Professor Baird, I am enabled to throw upon the screen to-night. These have been prepared by Mr. Merrill, of the Museum, who deserves great credit for the patient skill displayed in their preparation.

The following historical facts relating to this ancient mechanical implement, compiled from Lewis's pamphlet, may be of interest, viz.:



A GRINDSTONE OF THE SIXTEENTH CENTURY.

In the whole range of mechanics, with all modern developments and enlarged capabilities, there has been applied no mechanism nor process yet able to supersede the grindstone in its peculiar office. It is the one thing in mechanic arts that improvement has not added to, or invention displaced; while the pruning hook and plough are of equal antiquity, the spirit of improvement has touched both but left the grindstone unchanged. Its utility in the early ages was great, and science has not lessened its value any by its perfection of other means for like results. It has been found in use among uncivilized people, and yet has its place with nations most advanced. Writers of fiction knew it would not conflict with the appearance of truth to ascribe it a place among barbarians. It is among the few implements of handicraft mentioned in scripture, though there only named for milling purposes; it is the same in form and in universal use—a round revolving stone. In a scriptural research for the articles of handicraft mentioned then, we can look through the "eye of a needle" and find the grindstone beyond, its origin lost in the darkness of antiquity. It is not meant to confound the millstone of antiquity with the grindstone of to-day, which the encyclopædia mentions as "a flattish circular stone of various diameters, employed in the cutting and sharpening of edged tools, precious stones, etc., and the grinding of steel, glass, pottery and the like. They are made of sandstone, or sandstone grit." The grindstone now has scarcely a wider capability or greater usefulness than when we first heard of it. Although limited as its qualifications may be, it serves its purpose as nothing else can. Improvement has furnished us wheels of composition which only to some extent serve some of its purposes, but the grindstone still remains unsupplanted. It is a tool of the utmost nicety in proper hands and properly understood, and is capable of performing with speed and precision its limited agency beyond the powers of any modern tool. It is perhaps found best handled in its purpose of grinding dies for cut nails, where its proper use constitutes an occupation not to be attained very perfectly by a short apprenticeship with it. That known as "beadstone," used by makers of cut nails, is a tool of the utmost perfection of workmanship, not to be meddled with by the inexperienced, however lightly, without the result being noticed by the eye of the experienced nailer. The milling machine, the planer, the file, the lathe and emery wheel, do much of the work of the grindstone, but it still performs to perfection its needful though limited purposes. The importance and nicety of it, as a means to a purpose, is only known by those who know how to prepare and keep it in order.

Its utility or importance could not be guessed at, were one to look at a crooked and badly kept grindstone; but in the hands of those who know its merit, with its even surface running as true as any turned wheel, it will perform work with a rapidity and precision attainable by no other means. In the hands of those who are learned in its use and keeping, it is capable of adaptation to intricate and fine work, but with those who do not understand it, it is rude, and the very opposite of what the educated craftsman would select for any purpose of fine employment.

An heirloom of antiquity, but used among us as we received it, and without any attachment or improvement; capable of its complete functions only when well kept and well applied, and this is only found with those whose craft-education is solely to handle it. It alone can cut and shape expeditiously that which is prepared to cut and shape all other hard materials—cast-steel hardened. It is still employed to give the finest edge, the most even surface, the brightest polish, and is the quickest to accomplish it. The emery wheel does but a few of its purposes, and nothing that we have could supply its place. The file has its own peculiar uses, but in contact with the grindstone, its thousand small cutting edges would be reduced to polished plainness. It is found a necessary implement on the farm, and is still required where the finest of instruments are made, or the hardest of metals are worked. It has come to us as we have it, and in all likelihood will pass on down to other ages the same—a simple circular stone, swiftly revolving on an axle.

It accompanies those who "go down to the sea in great ships," and moves along the frontier with the advance of civilization. All nations use it, and it is perhaps, with all, the one piece of mechanism that bears the same form, and is the same in principle. More or less directly it takes part in the greatest modern material enterprises; it has, no doubt, assisted to fashion the implements of many of the lost arts, and is still needed in many of the requirements of arts of the present day.

As ages revolve and invention gives to the world new devices, may it be found more the agent in forming the ploughshare and pruning hook than in sharpening the sword.

Twinkling of Stars during Auroras.—Montigny finds that the scintillation of the stars increases during auroras, the increase being more strongly marked in winter. The difference is most noticeable in the northern stars. When a magnetic disturbance is shown at the Brussels Observatory, at the same moment with the observation of scintillation, the intensity often increases. He proposes to make the phenomenon the subject of a special investigation, in order to discover the cause of the remarkable coincidence.—*Bull. de l'Acad. de Belge,* iv, 303. C.

THE GLOVER TOWER AND THE WORKING OF SULPHURIC ACID CHAMBERS.

By Moses A. Walsh.

[Read before the Chemical Section of the Franklin Institute, June 5, 1883.]

It may be conceded that systematic observation, with proper qualification of observers and sufficient means, is a never-failing source of improvement.

In the mechanical and chemical arts this continues to be true where development is well advanced no less than during the early stages of development.

The construction of tower which I submit to the notice of the Section admits of the widest application in the chemical arts, but for the present I speak of it only as applied to the Glover and Gay-Lussac towers in the working of sulphuric acid chambers.

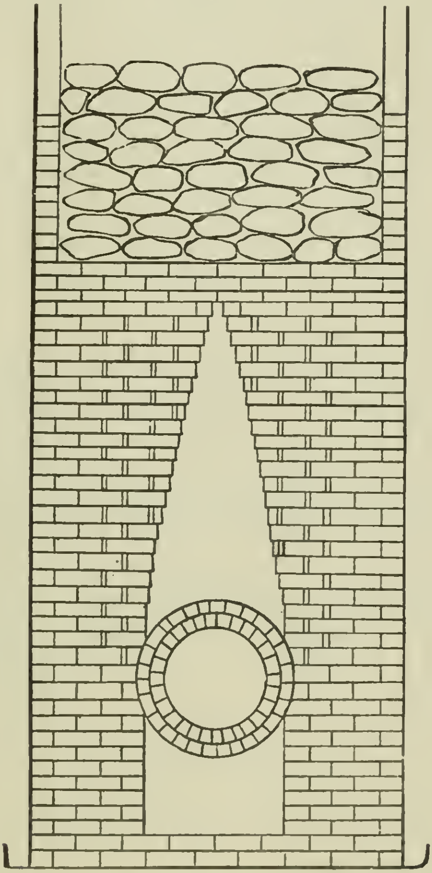
Last year, Mr. Henry Bower, the president of the Chemical Section, went to inspect some improvements I had made in the construction of towers and sulphur burners. In a conversation I had with him at the time, he remarked that there was a lack of mathematical precision in the action of all towers in use. A tower might work well or it might not work well. There were no means known by which it could be definitely determined beforehand that a tower would work in a precise manner after it was constructed; and when once constructed there was no directional control over its working. I showed him what I had done in the way of constructing towers designed, at least, to work with exactness.

I also pointed out a line of experiment by means of which, if not exactness, at least great improvement would result. I invoked Mr. Bower to use his influence with the Manufacturing Chemists' Association to induce it to undertake the burden of conducting the experiments. I have not since heard from him.

It is a fact that many Glover towers, especially, do not act in the smooth, efficient way of denitrating nitrous vitriol mentioned by Lunge. Where the acid from the Glover tower is used in the manufacture of alkali, the occasional presence of a small quantity of N_2O_3 is not observable, and even in larger amounts not prejudicial; but where the acid is used in other branches of manufacture, as is exclusively the case in America, such as the manufacture of alum, chlorhydric acid, etc., the presence of a small amount of nitrous acid becomes seriously manifest, as more than one manufacturer has found.

It was just such manufactures as these, where even traces of nitrous acid were prejudicial, that led me to seek a method by which certainty of denitration in the Glover tower could be insured.

Fig. 1.



that under the best circumstances $2\frac{1}{2}$ per cent. to $3\frac{1}{2}$ per cent. of nitrate of soda were required to maintain the waste of nitre going on in the chamber process. Little or no nitrous acid would be found in the acid from the tower, while the amount of nitrate potted was small, below 3 per cent.; but when the percentage was increased from any

The incentive to seek in this direction was increased by the fact cause, such as starting up after stoppage, the acid from the tower would contain very sensible quantities of nitrous acid, and the chamber process would be robbed of "nitre" by so much as went to injure the manufacture in which the acid was used. Loss of "nitre" elsewhere in the process could be accounted for and controlled. In each case brought under observaticn, the re-absorption of nitrous acid at the bottom of the tower was found to be due to mechanical causes originating in the defective construction of the Glover tower. One of these towers was supplied with burner gas through a pipe of 900 inches sectional area. The gas entered underneath an arch perforated with sixteen holes having an aggregate area of 260 inches, and the whole of the gas from the 900-inch pipe had to pass through these holes.

Interior observations were made of the descending acid and the ascending gases while the tower was at work, with simultaneous observations in the chambers and analyses of the acid coming from the tower. The object was to determine connection between mechanical conditions and chemical results.

The chambers connected with the tower had 88,000 cubic feet capacity, not counting towers nor draught pipes. The chambers having been stopped for repairs, were started with 4,320 lbs. seconds sulphur in 21 hours and 10 per cent. of nitrate. Acid began to form at once in the tower, but the chambers were slow in getting into condition, and the acid running from the tower was found to contain nitrous acid equal to 4 per cent. of the nitrate of soda potted. An assay of this acid was made every hour, and this and all other observations recorded. At the proper time the nitre potted was decreased, and Gay-Lussac and chamber acid run on, maintaining between the two as nearly as could be 10 per cent. of nitre.

The charge by potting was reduced to 2½ per cent., and it was not until then that the acid from the tower ran free from nitrogen oxides, and if at any time afterwards the charge of nitre by potting was increased beyond 3 per cent. or 3½ per cent., the acid from the tower was found to contain "nitre."

The acid in the tower was observed to descend in large drops and broken streams. These results were arrived at:

1. The acid distributed in the upper portions of the tower was collected into streamlets in the lower portion.

2. The acid in drops and streamlets, and in proportion to the volume of the drops and streamlets, is in a condition more favorable for the

absorption of nitrous acid than it is for denitration by sulphurous acid.

For comparison afterwards .I state results of working these chambers for one whole year.

Chamber space per lb. sulphur, 20·37.

Nitrate of soda potted, 2·8 per cent.

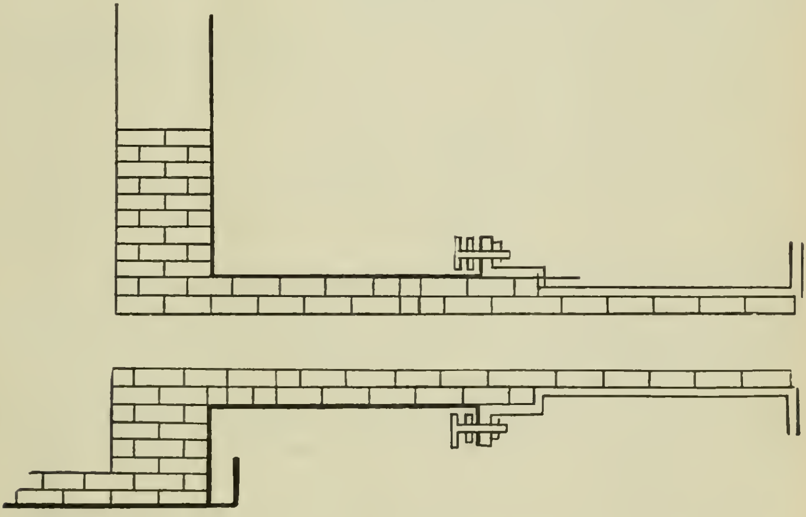
By the rule in Mr. H. Pemberton, Jr.'s paper, the case stands thus:

$$10 \times 20{\cdot}37 = 203{\cdot}7$$

instead of 280 to 300. The yield of H_2SO_4 was 288 per 100 sulphur consumed.

Mr. Pemberton, Jr., omitted to state this last result in the enforcement of his rule.

Fig. 2.



Being called upon to design and construct a Glover tower for another set of chambers, of 148,000 cubic feet capacity, I determined to avoid most of the defects observed in towers previously constructed. With this object, I had recourse to a device which I had designed some years before. This was to dispense with the arch entirely, with its disadvantages of contracted apertures and heavy side thrust, and also to avoid the use of lead covered bearings. This latter plan is quite inadmissible in the construction of the Glover tower, although I have heard of Glover towers being so constructed, with what result I never heard; but to run such a tower dry, even for never so short a time, must result in disaster. Lead covered iron bars are bad, as I have seen, because the acid trickling over the lead wears grooves in it and eventually exposes the iron to destruction.

It will be seen from the accompanying sketches that my device is something in the form of a Gothic arch, forming a large chamber at the bottom of the tower, and so constructed that the whole weight of the contents of the tower rests upon the bottom. It will be seen from Fig. 2 that the bond of the tower, with the pipe, effectually protects the lead from the action of the hot burner gas, if at any time the tower has to be run dry. If one stands inside the chamber. Fig. 1, he can see that some hundreds of apertures are provided for the ascending gases, and that the descending acid can nowhere form a drop or a streamlet. It must of necessity form an extremely thin and continuous film over a very extensive surface.

Thus the conditions observed in the tower before described are reversed in this tower.

1. The acid distributed in the upper portions of the tower are still further distributed at the bottom.

2. The acid in a thin film is in a condition more favorable for denitration by sulphurous acid than it is for the absorption of nitrogen oxides.

In these chambers 7,250 lbs. sulphur were used, and 10 per cent. nitrate of soda, 8,400 lbs. sulphur for a time was used, with nitrous vitriol and pot charges equal to 11 per cent. to 12 per cent. nitrate.

The pot charges of nitrate were decreased to 3 per cent., 2 per cent., $1\frac{1}{2}$ per cent., 1 per cent., and $\frac{3}{4}$ per cent. The acid running from the tower was frequently assayed, and from the first no trace of nitrous acid was found.

Taking a month's run of 30 days, 217,500 lbs. sulphur were burned, and 2,466 lbs. nitrate of soda potted. This gives a chamber space of 20·4 cubic feet per lb. sulphur burned, and 1·13 per cent. nitrate of soda potted.

The daily test of nitrous vitriol for the month showed that the average supply to the chambers from potting and nitrous vitriol combined was equal to 10·11 per cent. nitrate of soda.

$$10{\cdot}11 \times 20{\cdot}4 = 206{\cdot}24.$$

The yield of H_2SO_4 for a whole year was 300·48 from 100 sulphur. But the average consumption of nitre for the year was 1·48 per cent.

This result was traceable to three causes:

1. Perfect absorption in the Gay-Lussac tower.
2. Perfect denitration in the Glover tower.
3. Practically eliminating the influence of some of the most serious causes of disturbance in the chamber process, viz., high and variable winds, gusts of wind and the states of the atmosphere indicated by the barometer.

In another set of chambers of 98,692 cubic feet capacity, working without Glover or Gay-Lussac towers, 4,320 lbs. sulphur were used in 24 hours with a consumption of 8 per cent. nitre. This gives a chamber space of 22·8 cubic feet per lb. sulphur. Where 4,800 lbs. sulphur were used, giving a chamber space of 20·5 cubic feet, 10 per cent. nitre had to be used. The yield of H_2SO_4 for one whole year was 294·24 per 100 sulphur.

By the rule of Mr. H. Pemberton, Jr., the case would stand thus:

$$8 \times 22{\cdot}8 = 182{\cdot}4$$
$$10 \times 20{\cdot}5 = 205{\cdot}$$
$$\text{Mean, } 192{\cdot}7$$

And Mr. Pemberton's rule that percentage of nitre multiplied by chamber space shall equal 280 to 300, giving a mean of 290, when applied to chambers in which sulphur is used, is wrong by just this difference of one-third. The rule applies, and is followed when pyrites is used instead of sulphur, for making sulphuric acid, as then the chamber space is virtually reduced one third on account of the introduction of atmospheric nitrogen through the combustion of the Fe into $Fe\,S_2$ simultaneously with the combustion of the S_2. The rule when applied to the use of sulphur, is a very safe one to follow, as respects yields, as it should give the best results even where skill is not the best, but where the best return for outlay of capital upon sulphuric acid chambers is sought, that is dollars and cents, the chambers will have to be worked by another rule, viz., the product of the percentage of nitre by the number of cubic feet of chamber space per lb. sulphur burnt in 24 hours shall equal 200.

I hope, with Mr. Pemberton, that others will give the result of observation and experience in this matter.

ON RADIANT MATTER SPECTROSCOPY: A NEW METHOD OF SPECTRUM ANALYSIS.*

By William Crookes, F.R.S.

For several years I have been examining the phenomena presented by various substances when struck by the molecular discharge from the negative pole in a highly exhausted tube. I have ventured to call this discharge "radiant matter," and under its influence a large number of substances emit phosphorescent light, some faintly and others with great intensity. On examining the emitted light in the spectroscope most bodies give a faint continuous spectrum, with a more or less decided concentration in one part of the spectrum, the superficial color of the phosphorescing substance being governed by this preponderating emission in one or other part of the spectrum. Sometimes, but more rarely, the spectrum of the phosphorescent light is discontinuous, and it is to bodies manifesting this phenomena that my attention has been specially directed.

For a long time past I have been haunted by a bright citron-colored band or line appearing in these phosphorescent spectra, sometimes as a sharp line, at others as a broader nebulous band, but having always a characteristic appearance and occuring uniformly in the same spot. The best way to bring out the band is to treat the substance under examination with strong sulphuric acid, drive off excess of acid by heat, and finally to raise the temperature to redness. The anhydrous sulphate thus left frequently shows the citron band in the radiant matter tube, when before this treatment the original substance shows nothing. I soon came to the conclusion that the substance I was in search of was an earth, but on attempting to determine its chemical properties I was baffled.

Much chemical evidence tended to support the view that the band might be due to a compound of lime. By neglecting the portion showing least citron band, and separating all the elements present which gave little or none, I could generally concentrate the citron band into a solution which—according to our present knowledge of analytical chemistry—should contain little else than the earths, alkaline earths, and alkalies. Ammonia added to this solution would precipitate an earth, and in the filtrate oxalic acid would precipitate an insoluble oxalate, showing the citron band strongly. This was found on analysis to consist of strontic and calcic oxalates. The strontia being separated, the remaining lime formed an oxalate which gave the citron band.

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* Abstract of the Bakerian Lecture delivered before the Royal Society, May 31, 1883.

So far all the chemical evidence went to show that the band-forming substance was calcium, and further tests tried with the purified oxalate confirmed this inference. Every analytical test to which it was subjected showed lime, and nothing but lime; all the salts which were prepared from it resembled those of lime, both physically and chemically; the flame spectrum gave the calcium lines with extraordinary purity and brilliancy; and, finally, the atomic weight taken with great care, came out almost the same as that for calcium, 39·9 as against Ca 40.

On further examination it was found that most native compounds of lime gave the citron band. It was found in clear and colorless Iceland spar, native calcic phosphate, a crystal of arragonite, a stalactite of calcic carbonate from Gibraltar, cinnamon stone (lime alumina garnet), iron slag from a blast-furnace, pink coral, commercial plaster of Paris, and most specimens of ordinary burnt lime.

Evidence stronger than this in favor of the view that the citron band was an inherent characteristic of calcium could scarcely be; but, on the other hand, there was evidence equally conclusive that the band was not essential to calcium.

Starting with a lime compound which showed the citron band, I could always obtain a calcic oxalate which gave the band stronger than the original substance; but if I started with a lime compound which originally gave no citron band, I could never by any means, chemical or physical, constrain the lime or the earthy precipitate to yield a citron band.

The only explanation that I could see for this anomaly was that the elusive citron band was caused by some element precipitated with the calcic oxalate, but present in a quantity too small to be detected by ordinary chemical means. The calcic oxalate was ignited and dissolved in hydrochloric acid, and fractionally precipitated in three portions with ammonic oxalate, the first and third portions being comparatively small. They were then tested in the radiant matter tube. All three portions showed the citron band, but the portion which came down first gave the band decidedly the strongest, and the third portion precipitated showed it weakest.

It having been found that the substance giving the citron band formed a sulphate more soluble in water than calcic sulphate, four pounds weight of commercial plaster of Paris, which showed very faint traces of the citron band, were mixed with water and poured on a large filter. A few ounces of water were poured on, and after passing through, poured back, and the exhaustion repeated several times. The aqueous extract was then evaporated to dryness, ignited with sulphuric acid, ground in a mortar with small successive quantities of water, and precipitated with ammonic oxalate. The precipitate, ignited with sulphuric acid, showed the citron band very fairly, far more intensely than it was seen in the original calcic sulphate.

These experiments are conclusive in proving that the citron band is not due to calcium, but to some other element, probably one of the earthy metals, occurring in very minute quantities but widely distributed along with calcium, and I at once commenced experiments to find a more abundant supply of the body sought for. Amongst other substances tested I may note the following as giving a more or less decided citron band in the spectrum when treated with sulphuric acid in the manner indicated above: Crystallized barytic chlorate, heavy spar, common lime-stone, strontic nitrate, native strontic carbonate, crystallized uranic nitrate, commercial magnesic sulphate, commercial potassic sulphate, tobacco ash, Wagnerite (magnesic phosphate and fluoride), zircon, cerite, and commercial ceric oxalate.

Some specimens of zircon appeared sufficiently rich to make it probable that here might be found an available source of the citron-band yielding body. I found it in crystals from Green River, North Carolina, from Ceylon, from Expailly, from Miask (Oural), and from Brevig, and having a good supply of North Carolina zircons, these were worked up by a process given in detail in the paper.

I may condense a year's work on zircon,—over ten pounds weight of crystals from North Carolina having been worked up—by stating that the result was comprised in about 300 grains of an earthy residue, and about two ounces of oxalate, chiefly calcic; the former gave the citron band very well.

The zirconia prepared from these zircons, when tested, sometimes showed the citron band, and at other times none. A zirconia rich in citron band, fractionally precipitated by ammonia, yielded precipitates of increasing richness, the last fraction showing the citron band strongly.

The calcic oxalate obtained from zircon gave unsatisfactory results, so attention was directed to the earthy residue. This was found to be of highly complex character, containing thoria, ceria, lanthana, didymia, yttria, and probably some of the newly-discovered rarer earths.

The position of the citron band in the spectrum falls exactly on the strongest absorption band of didymium, so that a piece of didymium glass or cell of solution of the nitrate entirely obliterates the citron band. This naturally suggested that the band was due to didymium.

Cerite was accordingly the next mineral experimented on. The powdered mineral tested in the tube in the original way gives a good citron band. The mixed earths after extraction were converted into sulphates, dissolved in water, and the cerium metals precipitated by long digestion with excess of potassic sulphate.

The precipitated double sulphates were converted into oxalates, and after ignition and treatment with sulphuric acid, the mixed ceria, lanthana, and didymia were tested in the radiant matter tube, but the merest trace only of citron band was visible.

This experiment proved the inadequacy of the didymium explanation, and further tests showed that not only could I get no citron band in pure didymium compounds, but the spectrum entirely failed to detect didymium in many solutions of the earth which gave the citron band brilliantly.

Attention was now turned to the solution filtered from the insoluble double sulphates. Potash was added, and the precipitate filtered off, and tested in a radiant matter tube. The spectrum, of extraordinary brilliancy, was far brighter than any I had hitherto obtained. Unfortunately, however, the quantity was too small to be subjected to very accurate chemical analysis.

Search was now made amongst other minerals rich in the rarer earths. Thorite was finely powdered, treated with sulphuric acid, and tested in the radiant matter tube. It gave the citron spectrum most brilliantly—equal in fact to the mixture of earths obtained from zircons at so great an expenditure of time and trouble. Orangite treated in the same manner gave almost as good a spectrum. Pure thorinic sulphate prepared by myself was found not to give the citron band, but three specimens prepared and given to me by friends all gave it, so it was not unlikely that in thorite and orangite might at last be found a good source of the long-sought element—that in fact the body I was hunting for, if not thorina, might possibly be Bahr's hypothetical Wasium. Two pounds of orangite and thorite were extracted with hydrochloric acid. The solution was precipitated with potassic sulphate, taking the usual precautions to secure complete precipitation. A bulky precipitate ensued, which containad the thorina and cerium earths. These were separated and tested, and found to give only a faint citron band.

The solution of earthy sulphates soluble in potassic sulphate was precipitated with ammonic oxalate. The precipitate ignited with sulphuric acid, and tested in a radiant matter tube, gave the citron spectrum with great brilliancy.

Certain chemical facts concerning the behavior of the sought-for element which came out during the course of the tentative trials described in the paper considerably narrowed the list amongst which it might probably be found. All the evidence tends to show that it belongs to the group of earthy metals, consisting of aluminium, beryllium, thorium, zirconium, cerium, lanthanum, didymium, and the yttrium family, together with titanium, tantalum, and niobium. The sought-for earth is insoluble in excess of potash; this excludes aluminium and beryllium. It is not precipitated by continued boiling with sodic thiosulphate; this excludes aluminium, thorium, and zirconium. Fused with acid potassic sulphate, the resulting compound is readily soluble in cold water; this excludes tantalum and niobium. Evaporating to dryness with hydrochloric acid and heating for some time does not render the mass insoluble in water; this excludes titanium and silicium. It is easily soluble in an excess of a saturated solution of potassic sulphate; this excludes thorium, the cerium group, some of the numerous members of the yttrium group, and zirconium. The only remaining elements among which this elusive body would probably be found are those members of the yttrium family which are not precipitated by potassic sulphate.

The yttria earths form a somewhat numerous family. Fortunately for chemists, a mineral rich in yttria earths—samarskite—has been found lately in large quantity in Mitchell County, North Carolina, and to this mineral I accordingly now directed my attention.

The following list of elements of the yttrium and its allied families said to occur in samarskite and similar minerals may be considered complete to the present time.

Name.	Absorption Spectrum.	Hydrogen equivalent of Metal.* (Type of Oxide M_2O.)
Cerium	No	47·1
Decipium	Yes	57·0
Didymium	Yes	48·5
Didymium *β*	Yes	47·0
Erbium	Yes	55·3
Holmium	Yes	54·0
Lanthanum	No	46·0
Mosandrum	No	51·2
Samarium	Yes	50·0
Scandium	No	14·7
Terbium	No	49·5
Thulium	Yes	56·5
Ytterbium	No	57·9
Yttrium	No	29·7
Yttrium *α*	No	52·2
Yttrium *β*	Yes	49·7

Some of these claimants it is certain will not stand the test of further scrutiny. Thus samarium and yttrium *β* are in all probability identical; and I have not included philippium, as Roscoe has conclusively proved that this is a mixture of terbium and yttrium, and my own results confirm those of Roscoe. Moreover, some of these so-called elements will probably turn out to be mixtures of other known elements. But in the confessedly very imperfect state of our knowledge of the chemistry of these metals it is not safe for me in this research to assume that any one of them will surely not survive. The complete list as it stands will, therefore, be taken to contain all hitherto claimed as new, although it is almost certain to include too many.

In the second column "Yes" or "No" indicates whether the solutions give an absorption spectrum when examined by transmitted light. After numerous experiments I satisfied myself that the metal giving the citron band spectrum was not one of those giving an absorption spectrum. The possible elements, therefore, became narrowed to the following list: Cerium, lanthanum, mosandrum, scandium, terbium, thorium, ytterbium, yttrium, yttrium *α* and zirconium.

Of these the potassic sulphate reaction excludes cerium, lanthanum, scandium, thorium, yttrium *a*, and zirconium, so there are left only the following:

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* As it is at present doubtful whether the oxides of several of the metals in this table belong to the type M_2O, M_2O_3, or MO, I have, for the sake of uniformity, and simplicity in calculating the values from the composition of their salts, by which these metals are chiefly discriminated, taken the type of oxide to be M_2O.

Mosandrum,	Terbium,
Ytterbium,	Yttrium.

Certain chemical reactions for a long time made me dismiss yttrium from the first list of likely bodies. In my analysis of zircons, towards the latter part of the process, I used the following process to separate the iron: The solution mixed with tartaric acid and excess of ammonia was allowed to stand for some time. A small quantity of a precipitate gradually formed, which was filtered off, and it was this filtrate, after separating the iron with ammonic sulphide, that yielded the greatest quantity of substance giving the citron band. Now one of the methods of separating yttria from alumina, berylla, thoria, and zirconia is to precipitate it as tartrate in the presence of excesses of ammonia, the other earths remaining in solution. Fresenius says: "The precipitation ensues only after some time, but it is complete."

The precipitate thus obtained with tartaric acid and ammonia, should therefore contain all the yttria—*it gave no citron band whatever in the radiant matter tube;* whilst the residue, which should be free from yttria, proved for a long time the only source of material wherewith to investigate the chemical properties of the body giving the citron spectrum.

Another reason which made me, at this stage of the research, pass over yttria, was that I had already tested this earth in the radiant matter tube. In a paper on "Discontinuous Phosphorescent Spectra in High Vacua," read before the Royal Society, May 19, 1881, I said: "Yttria shows a dull greenish light giving a continuous spectrum."

For these reasons I for a long time omitted yttria from my list of possible bodies, and considered that the earth, if not a new one, might turn out to be either mosandra, terbia, or ytterbia.

About 15 lbs. weight of samarskite was worked up, partly by the hydrofluoric acid method of Lawrence Smith, and partly by fusion with potassic bisulphate.

These methods both gave as a result a large quantity of mixed earths containing most, if not all, the bodies enumerated in the foregoing list. Tested in the radiant matter tube this mixture gave the citron spectrum very brilliantly.

These earths were treated by a series of chemical processes too long and complicated to describe in this abstract, and the result of about five hundred fractional precipitations gave me a mixture of earths having an H equivalent, M=48, and showing a strong absorption spectrum; a mixture having an H equivalent, M=33, having no absorption spectrum; and intermediate earths.

In the radiant matter tube all these fractions gave the citron band spectrum well, but that of the earth of lowest equivalent was much the brightest, and that of the highest equivalent the least intense.

Three methods are available for the partial separation of these earths, and for the complete purification of any one of them. The formic acid process is best for separating terbia, as terbic formate is difficultly soluble in water, the other formates being easibly soluble.

Fractional precipitation with oxalic acid separates first erbia, holmia and thulia, then terbia, and lastly yttria. This is the only method which is applicable for the separation of small quantities of terbia from yttria.

Fusing the nitrates separates ytterbia, erbia, holmia and thulia from yttria. It is not so applicable when terbia is present, and is most useful in purifying the gadolinite earths. This process is the only one known for separating ytterbia from yttria.

Selection must be made of these methods according to the mixture of earths under treatment, changing the method as one earth or the other becomes concentrated on one side or thrown out on the other. Each operation must be repeated many times before even approximate purity is attained. The operations are more analogous to the separation of members of homologous series of hydrocarbons by fractional distillation than to the separations in mineral chemistry as ordinarily adopted in the laboratory.

Pure terbia ignited with sulphuric acid and tested in the radiant matter tube shows no citron band spectrum.

A concentrated solution of the purest terbia obtained in this way, when examined by the spectroscope, showed no absorption lines whatever—proving the absence of erbium, holmium and thulium.

I did not attempt any separation of erbium, holmium and thulium from each other, as the evidence obtained was sufficient to show that the element giving the citron band spectrum was not one of these three metals. Likewise I had far too little material to enable me to enter on a work of such difficulty with any prospect of success.

The chemical characters of mosandra are so little known that I could not attempt to search for it. But as the citron band-forming earth always appeared concentrated amongst those whose double sulphates were most soluble in potassic sulphate,—and, of these, amongst those having the palest color and the lowest atomic weight,—it was scarcely conceivable that the earth I was in search of should ultimately prove to be one whose properties did not in any case correspond to these,—of a dark orange yellow color, forming a difficultly soluble double potassic sulphate, and having the very high equivalent of M=51·2; these being the properties ascribed to mosandra by the discoverer, Professor Lawrence Smith.

Ytterbia was prepared from gadolinite, as this mineral is said by Nilson to contain most ytterbia. It was separated from accompanying earths by processes described in the paper. The resulting earth gave at first a faint citron band spectrum, evidently due to impurity; on repeating the purification several times I at last succeeded in obtaining a white earth which gave only the merest trace of citron band spectrum. Its hydrogen equivalent, 58·0, and its chemical properties showed that it was probably Marignac's ytterbia. Subsequent experiments satisfied me that this earth did not contain more than 1-10,000th part of yttria. The extreme tediousness of the chemical operations necessary to obtain this high degree of purity, and the long time they required, prevented me from pushing these results beyond what was necessary to prove the special point at issue.

The yttria, purified as already described, might still contain traces of terbia, together with erbia, holmia and thulia. These were gradually removed by the fusing nitrate process. The atomic weight gradually got down to 31·0, but the spectra did not vary very much; that from the earth of lowest atomic weight being, however, the most brilliant.

Pure yttria is quite white. That from gadolinite on testing in the radiant matter tube gave a spectrum absolutely identical with that given by the zircon, cerite, thorite orangite, and samarskite yttria. Pure yttria was also prepared from yttro-tantalite, euxenite, tyrite, and also from plaster of Paris and common limestone. In no case could I detect any difference in the position or intensity of the lines shown by their phosphorescent spectra.

THE PHOSPHORESCENT SPECTRUM OF YTTRIA.

The spectrum shown by pure ignited yttric sulphate in a radiant matter tube is one of the most beautiful objects in the whole range of spectroscopy. The spectrum is best seen under low dispersion and not too narrow a slit. It consists essentially of a broad red band, an intensely brilliant citron band, and two almost equally brilliant green bands. Other fainter lines are also seen, but they are not characteristic. Colored drawings and maps of the spectrum to scale accompany the paper. This description applies to the spectrum shown either by pure yttric sulphate or by an earth tolerably rich in yttria. When traces are present, the citron band only is seen. A little more yttria brings out the first and then the second green band, and finally, as the proportion of yttria increases, the red and blue bands appear.

The paper next gives a description of experiments made with pure yttria, and with various compounds of it, to see which would give the most characteristic spectrum. The sulphate heated to redness was found to give the best results. Pure yttria precipitated by ammonia did not phosphoresce in the slightest degree, and, necessarily, no citron band spectrum was to be seen. The yttria was removed from the tube, converted into sulphate, heated to redness, and again tested. This time it gave the citron band magnificently. This shows what apparently trivial circumstances will alter the whole course of an investigation. In 1881, when searching for discontinuous phosphorescent spectra, I tried a similar experiment with pure precipitated yttria, and entirely missed its citron band spectrum. Had I first treated the yttria with sulphuric acid instead of testing the earth itself in the radiant matter tube the results would have been very different, and this research would probably have never been undertaken.

Yttria was now prepared by igniting the precipitated oxalate at a red heat. On testing it in the radiant matter tube it phosphoresced with feeble intensity, the light being about one-twentieth of that given by the ignited sulphate under similar conditions. The citron band was almost as sharp as the sodium line, and was shifted one division towards the blue end. The two green bands were visible, but very hazy and indistinct, and only to be resolved into bands with difficulty.

It is an old and probably a true saying that every element could be detected everywhere had we sufficiently delicate tests for it. Early observations had prepared me for the wide distribution of yttrium, and no sooner had the exquisite sensitiveness of this spectrum test forced itself on my notice than I sought for yttrium in other minerals. The facts which I had noticed in connection with the variation of the appearance of the citron spectrum, according to the quantity of yttrium present, showed that it might be possible to devise a process for the rough quantitative estimation of yttrium, and after several experiments a spectrum test was devised sufficiently delicate to detect one-millionth part of yttria in a mineral. A table is given showing the results of this quantitative spectrum analysis, from which it is seen that amongst other substances pink coral contains one part of yttrium in 200 parts; strontianite, one part of yttrium in 500 parts; chondrodite, from Mount Somma, one part in 4,000; calcite, one part in 10,000; ox bone, one part in 10,000; an earthy meteorite (Alfianello), one part in 100,000, and tobacco ash, one part in 1,000,000.

THE CAUSE OF EVIDENT MAGNETISM IN IRON, STEEL, AND OTHER MAGNETIC METALS.*

By Professor D. E. Hughes, F.R.S.

The extreme sensitiveness of the induction balance to all molecular changes in the structure of metals was remarked in my first paper on this subject to the Royal Society;† and in the case of iron and steel it is most remarkable, as the addition or substraction of $\frac{1}{500000}$ part, or the addition of the smallest iron filing to an already large balanced mass of iron, is at once rendered evident and measurable. Possessing such an invaluable instrument of research, I was desirous of investigating the molecular construction of iron and steel, but at once I met with a difficulty, viz., that magnetism itself completely changed the character of any piece of iron under investigation. Consequently, finding no help or explanation of the effects produced from any accepted theories of magnetism, I was forced to investigate, by means of the induction balance, the whole question of magnetism as existing in the interior of a magnet, and to determine the particular structure for each case, such as neutrality and polarity. In a recent paper to the Royal Society, upon the theory of magnetism,‡ I described the use of and demonstrations obtained by the induction balance. In this paper I propose to confine myself to demonstrations that can be repeated without it, and whose effects can be observed by the aid of ordinary magnetic direction needles. That magnetism is of a molecular nature has long been accepted, for it is evident that, no matter how much we divide a magnet, we still have its two poles in each separate portion, consequently we can easily imagine this division carried so far that we should at last arrive at the molecule itself possessing its two distinctive poles, consequently all theories of magnetism attempt some explanation of the cause of this molecular polarity, and the reason for apparent neutrality in a mass of iron. Couloumb and Poisson assume that each molecule is a sphere containing two distinct magnetic fluids, which in the state of neutrality are mixed together, but when polarized are separated from each other at opposite sides; and, in order to explain why these fluids are kept apart as in a permanent magnet, they had to assume, again, that each molecule contained a peculiar coercive force, whose functions were to prevent any change or mixing of these fluids when separated.

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* Read before the Society of Telegraph Engineers and of Electricians, May 24, 1883.

† "On an Induction Current Balance and Experimental Researches made therewith."—*Proceedings Royal Society*, March 29, p. 56, 1879.

‡ *Proceedings Royal Society*, May 10, 1883.

There is not one experimental evidence to prove the truth of this assumption; and as regards coercive force, we have direct experimental proof opposing this view, as we know that molecular rigidity or hardness, as in tempered steel, and molecular freedom or softness, as in soft iron, fulfill all the conditions of this assumed coercive force. Ampère's theory, based upon the analogy of electric currents, supposes elementary currents flowing around each molecule, and that in the neutral state these molecules are arranged haphazard in all directions, but that magnetization consists in arranging them symmetrically. The objections to Ampère's theory are numerous. 1st. We have no knowledge or experimental proof of any elementary electric currents continually flowing without any expenditure of energy. 2d. If we admit the assumption of electric currents around each molecule, the molecule itself would then be electro-magnetic, and the question still remains, what is polarity? Have the supposed electric currents separated the two assumed magnetic fluids contained in the molecule, as in Poisson's theory? or are the electric currents themselves magnetic, independent of the iron molecule? In order to produce the supposed heterogeneous arrangement of neutrality, Ampére's currents would have either to change their position upon the molecule, and have no fixed axis of rotation, or else the molecule, with its currents and polarities, would rotate, and thus be acting in accordance with the theory of De la Rive. 3d. This theory does not explain why (as in the case of soft iron) polarity should disappear whenever the exciting cause is removed, as in the case of transient magnetization. It would thus require a coercive force in iron to cause exactly one-half of the molecules to instantly reverse their direction, in order to pass from apparent external polarity to that of neutrality. The influence of mechanical vibrations and stress upon iron in facilitating or discharging its magnetism, as proved by Matteucci, 1847, in addition to the discovery by Page, 1837, of a molecular movement taking place in iron during its magnetization, producing audible sounds, and the discovery by Dr. Joule, 1842, of the elongation of iron when magnetized, led De la Rive, in his remarkable *Treatise on Electricity*, 1853, to give his theoretical views upon magnetism in the following remarkable words: "The whole of the magnetic molecular phenomena that we have been studying lead us to believe that the magnetization of a body is due to a particular arrangement of its molecules, originally endowed with magnetic virtue, but which in the natural state are so arranged that the magnetism of the body that they constitute is not apparent. Magnetism would, therefore, consist in disturbing this state of equilibrium, or in giving to the particles an arrangement that makes manifest the property with which they are endowed, and not in developing it in them. The coercitive force should be the resistance of the molecules to change their relative positions."

Wiedermann, in 1861, gives a theory in which he admits the fluids of Poisson, or the elementary currents of Ampère, as the cause of polarity of the molecule, but believes that the molecules are turned in a general direction in the case of polarity, and that in neutrality, like Ampère's, the magnetic axes of the molecules are turned in all directions. Maxwell, in his remarkable treatise on "Electricity and Magnetism," 1881, page 75, gives the following résumé of Weber's theory: "Weber's theory differs from Poisson's in assuming that the molecules of the iron are always magnets, even before the application of the magnetising force, but that in ordinary iron the magnetic axes of the molecules are turned indifferently in every direction, so that the iron, as a whole, exhibits no magnetic properties." And again, page 429, Maxwell says he agrees with Weber's views, and that neutrality, or unmagnetized iron, has the axes of its molecules placed indifferently in all directions, and that the act of magnetization consists in turning all the molecules so that their axes are either rendered all parallel to one direction, or at least deflected in that direction. I have quoted these several theories which admit of the inherent polarity of the molecule, and in that respect they entirely agree with my own; but the induction balance at once shows that they are erroneous in the most important part, for my researches have proved that neutrality is perfectly symmetrical, that there is no case of neutrality where the axes of the molecules are turned indifferently in all directions, and that we cannot obtain perfect neutrality except when the molecules form a complete closed circuit of attraction. I believe that a true theory of magnetism should admit of complete demonstration, that it should present no anomalies, and that all the known effects should at once be explained by it. From numerous researches I have gradually formed a theory of magnetism entirely based upon experimental results, and these have led me to the following conclusions:

1. That each molecule of a piece of iron, steel, or other magnetic metal is a separate and independent magnet, having its two poles and distribution of magnetic polarity exactly the same as its total evident magnetism when noticed upon a steel bar-magnet.

2. That each molecule, or its polarity, can be rotated in either direction upon its axis by torsion, stress, or by physical forces such as magnetism and electricity.

3. That the inherent polarity or magnetism of each molecule is a constant quantity like gravity; that it can neither be augmented nor destroyed.

4. That when we have external neutrality, or no apparent magnetism, the molecules, or their polarities, arrange themselves so as to satisfy their mutual attraction by the shortest path, and thus form a complete closed circuit of attraction.

5. That when magnetism becomes evident, the molecules or their polarities have all rotated symmetrically in a given direction, producing a north pole if rotated in that direction as regards the piece of steel, or a south pole if rotated in the opposite direction. Also, that in evident magnetism, we have still a symmetrical arrangement, but one whose circles of attraction are not completed except through an external armature joining both poles.

6. That we have permanent magnetism when the molecular rigidity, as in tempered steel, retains them in a given direction, and transient magnetism whenever the molecules rotate in comparative freedom, as in soft iron.

EXPERIMENTAL EVIDENCES.

In the above theory the coercive force of Poisson is replaced by molecular rigidity and freedom; and as the effects of mechanical vibrations, torsion, and stress upon the apparent destruction and facilitation of magnetism is well known, I will, before demonstrating the more serious parts of the theory, cite a few experiments to prove that molecular rigidity fulfils all the requirements of an assumed coercive force. The influence of vibrations, torsion, or stress of any kind upon a magnetized steel or iron rod may be seen by striking with a wooden mallet rods of hard and soft steel, also hard and soft iron previously magnetized to a known degree. The tempered steel, owing to its molecular rigidity, will lose but 5 per cent., the soft steel 60, hard iron 50, and soft Sweedish iron 99 per cent. of its magnetism, the amount of loss depending not so much upon whether the metal be steel or iron as upon its degree of hardness and softness; and as hard steel requires far more power to magnetize it to the same force than iron, it is possible to imagine a steel so hard that its molecules could not rotate, and that, consequently, no magnetism could be manifested from a given inducing cause, whilst a perfectly soft iron would give the maximum effect, and instantly return to its previous state. From this we might in error suppose that soft Swedish iron could not retain its magnetism, and that its natural state would be zero, or neutrality. The apparent disappearance of magnetism, however, is here due to the extreme freedom of motion of its molecules allowing them at once to follow the comparatively feeble directing force of the earth's magnetism. We can demonstrate this by feebly magnetizing a rod of soft iron held vertically, so that its north pole is at the lower portion. Upon removing the inducing magnet, or electro-magnetic coil, we find that the rod retains a powerful north polarity; but if magnetized in a contrary sense, then we have only *traces* of magnetism left upon the withdrawal of the inducing cause. To succeed in this experiment, as in all others where soft iron is mentioned, we should use the best Swedish charcoal iron, thoroughly annealed at high temperature. We find, again, that rods of steel or iron will lose far less magnetism when vibrated in the magnetic dip, or vertically, when their north poles are at the lowest extremity, than when horizontal, or still less than when their poles are contrary to those of the earth's field, and also that they will acquire their maximum magnetism from a given exciting cause when held vertically as described, and the molecules allowed greater freedom of motion to obey the directing influence by vibrations, torsion, stress, or blows upon the iron. Any influence that would tend to give greater freedom of motion, such as heat or mechanical trepidations, gives a far higher magnetic force to the iron than could be obtained without these aids.

In order to render visible the effects of motion upon magnetism, we may take two glass tubes, or ordinary vials, of any length or diameter, say 10 centimetres in length by 2 centimetres in diameter. If we now put iron filings in these tubes, leaving about one-third vacant, so as to allow complete freedom in the filings when shaken, we find that each tube, when magnetized, retains an equal amount of residual magnetism, and that this all disappears upon slightly shaking the tube. We are thus imitating the effects of vibration. But if in one of these tubes we pour melted resin (in fact, any slightly viscous liquid, such as petroleum suffices), we then render these filings more rigid, and then we can no longer produce by shaking the disappearance of its residual magnetism. In pouring in petroleum we have apparently been introducing a strong coercitive force, but we know that it can only have the mechanical effect of rendering the iron filings less free to turn, and so comparatively rigid. If we desire to see the effect of torsion, we have only to shake the filings so that when the tube is held horizontally the vacant space is above, and rotate it slightly (but without shaking) about a horizontal axis. Its remaining magnetism instantly disappears upon rotation, although we evidently have not changed the longitudinal position of its particles. A similar effect takes place upon a soft iron rod; for if we magnetize it, and observe its remaining magnetism, we find that, upon giving a slight torsion to this wire, its remaining magnetism instantly disappears—a similar effect to that in the rotating tube of iron filings. But if the iron is rendered more rigid by hammering, or steel rendered hard and rigid by tempering, torsions or vibrations have but little effect, as in the case of the filings rendered rigid as above mentioned. Thus we have no longer need of an assumed mysterious coercitive force to account for the retention of magnetism; for once knowing the mechanical qualities of iron and steel, and their degree of molecular rigidity or hardness, we can at once predict their retentive magnetic powers.*

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* "On the Molecular Rigidity of Tempered Steel," by Professor D. E. Hughes, F.R.S.—*Proceedings Institution of Mechanical Engineers*, pages 72–79, January, 1883.

ROTATION OF INHERENT POLARIZED MOLECULES.

Torsion, as well as mechanical vibrations, has, as we have seen, a powerful influence in aiding the molecules to overcome their inertia, and thus aid them to rotate in the direction of the inducing influence; and we may thus polarize strongly a flat soft iron rod by simply bending or vibrating it when held vertically, and if we measure the magnetic force obtained, we shall notice that the force is strictly relative to the degree of softness of the iron. Thus with hard steel we should obtain only traces of polarization, whilst with extremely pure soft Swedish iron we obtain the maximum of force. The bar of iron or steel, being held in the earth's magnetic field, of infinite size compared with the bar, and infinitely homogeneous, cannot deflect or weaken its surrounding field. Its lower portion being north, apparently strengthens it by its reaction, whilst its upper, south, apparently weakens the field; but, as Maxwell has shown, "the two poles of each molecule are equal and opposite; consequently, the sum of each molecule and the whole mass must be zero." We have a far greater induced polarity in iron or steel when the iron is in thin bars or small wires, and this we should expect, as the external molecules rotate directly under the influence of the earth's magnetism, whilst those forming the interior of the bar either rotate feebly, or, as in the case of very thick bars, actually act as an armature, preventing, by their influence, free rotation of the exterior molecules. Thus, as the sum of the two and equal polarities in a bar of iron is zero, it is evident that its polarity must be inherent. I have some remarkably pure soft Swedish iron wire, one millimetre in diameter, and as its inherent polar force seemed great when held vertically in the earth's magnetic field, I measured in the induction balance this force compared with a similar column of the magnetic atmosphere which it displaced. The inherent polarity of this wire, simply rendered evident by the earth's magnetism, was 15,600 times greater than the column it displaced. We cannot, either by induction, conduction, or concentration, produce a greater force in another body of similar displacement or size, otherwise we could easily create power from a feeble source. Thus the enormously greater magnetic power observed in iron than the same column of air which it displaces must be due to the inherent polarity of its molecules.

Amongst numerous bars of iron upon which I have experimented, one of ordinary hoop-iron, 2 centimetres wide, 40 centimetres long, and 1½ millimetre thick, not softened, possesses sufficient molecular rigidity to be apparently uninfluenced by earth's magnetism. When this rod is rendered neutral, we have but feeble polarity—mere traces when it is held vertically under the earth's magnetic influence; but if we apply a few successive torsions or vibrations to it when thus held, we have at once several thousand times greater polarity than before. Now, if iron had the power of deflecting or concentrating the earth's magnetism upon itself, it should not require the mechanical aid to molecular rotation given to it by these torsions or vibratoins. Thus we are forced to conclude at least the existence of the inherent polarity of the molecules; and, if we admit this, we must also, as a necessary consequence, admit the rotation of these molecules, else we cannot explain why mechanical vibrations allowing freedom of motion should always produce the polarity in accordance with the directing cause. I have already shown that torsion and vibrations *per se* are apparently destructive of magnetism; consequently in this case Poisson's two fluids and Ampère's parallel currents should, according to their theory, be mixed or heterogeneous, whilst according to the views I am sustaining the polarized molecules should obey, as compass needles, any magnetic directing cause whenever sufficient molecular freedom of motion allows free rotation. The inherent polarity of iron may again be observed by drawing a flat rod of soft iron over one or both poles of a permanent magnet. This rod will then be powerfully magnetized, its remaining magnetism, when separated from the magnet, being sufficiently powerful to strongly deflect a suspended direction needle. A few slight torsions or vibrations will then completely discharge it. Now, suppose this operation repeated successively many thousand times, if there was no inherent polarity we should have gradually drawn all the polarity out of the magnet, and discharged it into the atmosphere. Nothing of the kind takes place. The molecules of the iron are simply rotated each time, and the only energy in work expended or lost comes from the arm of the experimenter, and the energy required would be strictly in accordance with the molecular freedom, or softness and hardness of the iron and steel; thus, whilst soft iron could be easily polarized and discharged by mechanical torsions, hard-tempered steel would require a far greater amount. Dr. Warren De La Rue, F.R.S., kindly aided me in this part of the research by passing a current from his well-known chloride of silver battery through iron and steel wires. A condenser of 42·8 microfarad capacity, charged by 3360 cells, was used. We passed this enormous electric charge longitudinally through the wires, and observations were made as to whether any change whatever was produced in their quality or inherent polarity, the result being that these wires gave exactly the same magnetic polarity from a givin directing or inducing cause as before, being similar in nature and degree, consequently this enormous electric force had not changed or destroyed the original inherent polarity. If the molecules possess inherent polarity and rotate upon their axes, similar to a series of compass needles having a slight degree of frictional rigidity, then, upon passing one pole of a magnet above them, they would turn symmetrically in one direction, and drawing the same pole of the magnet in the contrary direction would rotate them, and they would then remain symmetrically in the opposite direction.

A precisely similar effect takes place in a soft iron rod placed east and west a few inches above a direction needle. Upon drawing the south pole of a powerful natural magnet at a few centimetres distance above the wire from east to west, the north polarities of the molecules successively turn in the direction of west, following the attraction of the south pole, as previously seen on the small compass needles. The rod is now magnetized with its north pole west, as indicated by the direction needle below any portion of this rod. Upon passing the same south pole of the natural magnet in a contrary direction, the molecules all rotate, their north poles still turning successively to the south pole of the permanent magnet until its arrival at the end from which the first magnetization commenced. The rod has now entirely changed its polarity, and its north pole is east. This phenomenon is well known in the ordinary magnetization of rods, where care is taken to draw the magnet always in a similar direction, or the poles would be reversed at each to and fro drawing. To account for this, on Couloumb-Poisson's theory, it would be requisite that, first, all the fluids be separated with their north fluids symmetrically in one direction, but on drawing back the magnet, these fluids would have to mix together, the north fluid passing through its south fluid to be finally opposite to its previous position, its coercive force doing the double work of allowing both fluids to mix and pass through each other, and finally keeping them entirely apart. Ampère's theory would require that from a haphazard arrangement the molecules should become symmetrically arranged upon the first passage of the magnet, then upon its reversed direction one half of the electric elementary currents should successively revolve in a contrary direction to arrive at neutrality before, finally, the other half followed the direction of the first half, and now all these currents would be revolving in the opposite direction to that upon the first magnetization. We thus see that both these theories, whilst resting altogether upon assumption, are extremely complicated and improbable. We might suppose, from the theory which I am advocating, that upon the rotation of the molecules there would be some disturbance or mechanical trepidation; and such is found to be the case, as first observed by Page, and afterwards verified by Dr. Joule and De la Rive, in the molecular sounds produced in iron upon its magnetization. Reis's first telephone was founded upon these sounds, and Du Moncel has made numerous researches upon this subject. In the last of my experiments cited, the sounds are too feeble to be heard, but by the application of the microphone these trepidations at once become audible.

That molecules of iron and other metals rotate with time, whose period becomes shortened by mechanical vibrations, is well known in metallurgy, the ultimate result being generally the passage from a fibrous condition, as in iron wires, to a high degree of crystallization. For many years I employed a circular vibrating spring as the regulator of speed of my printing telegraph instrument, and although this spring was so regulated by means of a frictional break, or "Frein," as not to surpass its limits of elasticity, these springs were constantly breaking after a few days' use, and, as a matter of urgent necessity, I made special researches into the cause of this breaking after a few days' constant vibratory action. I found at the point of rupture a high state of crystallization. Fibrous iron would thus become thoroughly crystallized and break in one day; the number of vibrations for an instrument in constant use during twenty-four hours being 1,209,600. Thus we could roughly estimate the life of iron in the form of one of these springs at one million vibrations. Copper crystallized in one hour, and all metals and alloys were inferior to steel, except aluminium bronze. The latter springs would stand six weeks' constant use, or some fifty millions of vibrations. I finally resolved this problem by spreading the amount of vibrating work over a spiral spring containing 3 metres of steel rod wound into the same space as previously held by the straight rod of 30 centimetres. By this means the average life of these springs has become five years. Evidently the molecules of these fibrous springs must have rotated under the vibrations, in order to produce crystals. The same phenomenon is observed in axles of carriages receiving constant trepidations, large crystals being always found at the point of fracture. Again, if we rapidly magnetize and demagnetize an iron rod, we have the production of evident heat, due to the constant motion of its molecules. Maxwell describes an experiment of Beetz, in which an exceedingly small filament of iron was deposited by electrotype, under the influence of a strong magnetic field, in order to arrive at the inherent polarity of comparatively few molecules, and, as its magnetic force was very great, he regards the experiment as conclusive. My own experiments show that we have far less external magnetic force from a solid bar than from a thin tube or flat bar of the same surface exposed to a limited exciting cause. We know that magnetism does not penetrate to a very great depth, and we also know that, if to a thin steel permanent magnet we place another piece unmagnetized, or, better still, a rod of soft iron, its external polarity is greatly reduced; consequently the external evidence of polarity is not a direct measure of the degree of rotation, nor of the total inherent polarity of its mass; We may have a great superficial *external* rotation superposed upon rotations of an opposite nature, as will be seen later; and thus the internal molecules of a magnet often act more or less as an external armature in closing its circle of attractions.

I have stated my belief that the molecule itself possesses its inherent polarity, which, like gravity, is an endowed quality for which we have no more reason to suspect the cause to be elementary electric currents than that elementary currents should be the cause of gravity, chemical affinity, or cohesion and its polar power of crystallization, most of which are effected by an electric current. We have a certain analogy between electric currents and magnetism, but not so great as the analogy between the magnetic polarity of a molecule and its other endowed qualities. Magnetism, like chemical affinity, cohesion, and crystallization, has its critical points. Faraday discovered that at red-yellow heat iron instantly lost its apparent polar magnetic power, to be as instantly restored at red heat, the critical point varying in iron, steel, etc., and being the lowest in nickel. This would be difficult to explain upon Ampère's theory, as we should have to admit the instant destruction or cessation of the elementary currents, to be again restored at a few degrees less temperature. It would be equally difficult to explain under my view, if it did not belong to a whole class of phenomena due to the possession by the molecules of various endowed qualities, of which chemistry and all our means of research can only teach us their critical points, without attempting to explain why, for instance, iron has a greater affinity for oxygen than gold. We know that it is so; we know that the molecules of all matter are endowed with certain qualities having certain critical points, and I can see no reason for separating their magnetic inherent polarity from their numerous other qualities.

NEUTRALITY.

The apparatus needed for researches upon evident external polarity requires no very great skill or thought, but simply an apparatus to measure correctly the force of the evident repulsion or attraction; in the case of neutrality, however, the external polarity disappears, and we consequently require special apparatus, together with the utmost care and reflection in its use. From numerous researches previously made by means of the induction balance, the results of which I have already published, I felt convinced that in investigating the cause of magnetism and neutrality I should have in it the aid of the most powerful instrument of research ever brought to bear upon the molecular construction of iron, as indeed of all metals. It neglects all forces which do not produce a change in the molecular structure, and enables us to penetrate at once to the interior of a magnet or piece of iron, observing only its peculiar structure and the change which takes place during magnetization or apparent neutrality. The induction balance is effected by three distinct arrangements of molecular structure in iron and steel, by means of which we have apparent external neutrality.

FIG. 1.

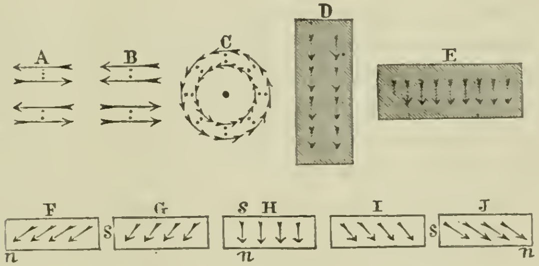


Fig. 1 shows several polar directions of the molecules as indicated by the arrows. Poisson assumed, as a necessity of his theory, that a molecule is spherical, but Dr. Joule's experimental proof of the elongation of iron by $\frac{1}{720000}$ of its length when magnetized proves at least that its form is not spherical; and, as I am unable at present to demonstrate my own views as to its exact form, I have simply indicated its polar direction by arrows—the dotted oval lines merely indicating its limits of free elastic rotation. In Fig. 1, at A, we have neutrality by the mutual attraction of each pair of molecules, being the shortest path in which they could satisfy their mutual attractions. At B we have the case of superposed magnetism of equal external value, rendering the wire or rod apparently neutral, although a lower series of molecules are rotated in the opposite direction to the upper series, giving to the rod opposite and equal polarities. At C we have the molecules arranged in a circular chain around the axis of a wire or rod through which an electric current has passed. At D we have the evident polarity induced by the earth's directive influence when a soft iron rod is held in the magnetic meridian. At E we have a longitudinal neutrality produced in the same rod when placed magnetic west, the polarity in the latter case being transversal. In all these cases we have a perfectly symmetrical arrangement, and I have not yet found a single case in well-annealed soft iron in which I could detect a heterogeneous arrangement, as supposed by Ampère, De la Rive, Weber, Wiedermann, and Maxwell. We can only study neutrality with perfectly soft Swedish iron. Hard iron and steel retain previous magnetizations, and an apparent external neutrality would in most cases be the superposition of one magnetism upon another of equal external force in the opposite direction, as shown at B, Fig. 1. Perfectly soft iron we can easily free, by vibrations, from the slightest trace of previous magnetism, and study the neutrality produced under varying conditions.

If we take a flat bar of soft iron, of 30 or more centimetres in length, and hold it vertically (giving while thus held a few torsions, vibrations, or better still, a few slight blows with a wooden mallet, in order to allow its molecules to rotate with perfect freedom), we find its lower end to be of strong north polarity, and its upper end south. On reversing the rod and repeating the vibrations, we find that its lower end has precisely a similar north polarity. Thus the iron is homogenous, and its polarity symmetrical. If we now magnetize this rod to produce a strong south pole at its lower portion, we can gradually reverse this polarity, by the influence of earth's magnetism, by slightly tapping the upper extremity with a small wooden mallet. If we observe this rod by means of a direction needle at all parts, and successively during its gradual passage from one polarity to the other, there will be no sudden break into a haphazard arrangement, but a gradual and perfectly symmetrical rotation from one direction to that of the opposite polarity. If this rod is placed east and west, having first, say, a north polarity to the right, we can gradually discharge or rotate the molecules to zero, and as gradually reverse the polarity by simply inclining the rod so as to be slightly influenced by earth's magnetism; and at no portion of this passage from one polarity to neutrality, and to that of the opposite name, will there be found a break of continuity of rotation or haphazard arrangement. If we rotate this rod slowly, horizontally or vertically, taking observations at each few degrees of rotation of an entire revolution, we find still the same gradual symmetrical change of polarity, and that its symmetry is as complete at neutrality as in evident polarity.

In all these cases there is no complete neutrality, the longitudinal polarity simply becoming transversal when the rod is east and west. F, G, H, I, J, Fig. 1, show this gradual change, H being neutral longitudinally, but polarized transversely. If, in place of the rod, we take a small square soft iron plate and allow its molecules freedom under the sole influence of the earth's magnetism, then we invariably find the polarity in the direction of the magnetic dip, no matter in what position it be held, and a sphere of soft iron could only be polarized in a similar direction. Thus we can never obtain complete external neutrality whilst the molecules have freedom and do not form an internal closed circle of mutual attractions; and, whatever theory we may adopt as to the cause of polarity in the molecule, such as Coulomb's Poisson's, Ampère's, there can exist no haphazard arrangement in perfectly soft iron, as long as it is free from all external causes except the influence of the earth; consequently these theories are wrong in one of their most essential parts. We can, however, produce a closed circle of mutual attractions in iron and steel, producing complete neutrality as long as the structure is not destroyed by some stronger external directing influence. Oersted discovered that an external magnetic needle places itself perpendicular to an electric current; and we should expect that, if the molecules of an iron wire possessed inherent polarity and could rotate, a similar effect would take place in the interior of the wire to that observed by Oersted. Wiedermann first remarked this effect, and it has been known as circular magnetism. This circle, however, consists really in each molecule having placed itself perpendicular to the current, simply obeying Oersted's law, and thus forming a complete circle in which the mutual attractions of the molecules forming that circle are satisfied, as shown at C, Fig. 1. This wire becomes completely neutral, any previous symmetrical arrangement of polarity rotating to form its complete circle of attractions; and we can thus form in hard iron and steel a neutrality extremely difficult to break up or destroy. We have evident proof that this neutrality consists of a closed chain, or circle, as by torsion we can partially deflect them on either side; thus from a perfect externally neutral wire, producing either polarity, by simple mechanical angular displacement of the molecules as by right or left-handed torsion. If we magnetize a wire placed east and west it will retain this polarity until freed by vibrations, as already remarked. If we pass an electric current through this magnetised wire, we can notice the gradual rotation of the molecules, and the formation of the circular neutrality. If we commence with a weak current, gradually increasing its strength, we can rotate them, as slowly as may be desired. There is no sudden break or haphazard moment of neutrality; the movements to perfect zero are accomplished with perfect symmetry throughout.

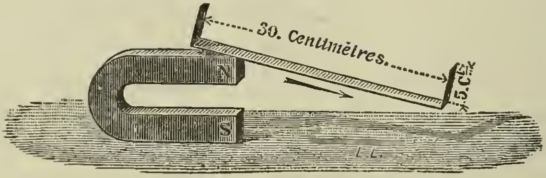
We can produce a more perfect and shorter circle of attractions by the superposition of magnetism, as at B, Fig. 1. If we magnetize a piece of steel or iron in a given direction with a strong magnetic directing power, the magnetism penetrates to a certain depth. If we slightly diminish the magnetising power, and magnetize the rod in a contrary direction, we may reduce it to zero, by the superposition of an exterior magnetism upon one of a contrary name existing at a greater depth; and if we continue this operation, gradually diminishing the force at each reversal, we can easily superpose ten or more distinct symmetrical arrangements, and, as their mutual attractions are satisfied in a shorter circle than in that produced by electricity, it is extremely difficult to destroy this formation when once produced. The induction balance affords also some reasons for believing that the molecules not only form a closed circle of attractions, as at B, but that they can mutually react upon each other, so as to close a circle of attractions as a double molecule, as shown at A. The experimental evidence, however, is not sufficient to dwell on this point, as the neutrality obtained by superposition is somewhat similar in its external effects. We can produce a perfectly symmetrical closed circle of attractions of the nature of the neutrality of C, Fig. 1, by forming a steel wire into a closed circle, 10 centimetres in diameter, if this wire is well joined at its extremities by twisting and soldering. We can then magnetize this ring by slowly revolving it at the extremity of one pole of a strong permanent magnet; and, to avoid consequent poles at the part last touching the magnet, we should have a graduating wedge of wood so that whilst revolving it may be gradually removed to greater distance. This wire will then contain no consequent points of external magnetism; it will be found perfectly neutral in all parts of its closed circle. Its neutrality is similar to C, Fig. 1; for if we cut this wire at any point we find extremely strong magnetic polarity, being magnetized by this method to saturation, and having retained (which it will indefinitely) its circle of attractions complete.

I have already shown that soft iron, when its molecules are allowed perfect freedom by vibration, invariably takes the polarity of the external directing influence, such as that of the earth, and it does so even with greater freedom under the influence of heat Manufacturers of electro-magnets for telegraphic instruments are very careful to choose the softest iron and thoroughly anneal it; but very few recognize the importance as regards the position of the iron whilst annealing it under the earth's directing influence. The fact, however, has long since been observed. Dr. Hooke, 1684, remarked that steel or iron was magnetized when heated to redness and placed in the magnetic meridian. I have slightly varied this experiment by heating to redness three similar steel bars, two of which had been previously magnetized to saturation, and placed separately with contrary polarity as regards each other, the third being neutral. Upon cooling, these three bars were found to have identical and similar polarity. Thus the molecules of this most rigid material, cast steel, had become free at red heat, and rotated under the earth's magnetic influence, giving exactly the same force on each; consequently the previous magnetization of two of these bars had neither augmented nor weakened the inherent polarity of their molecules. Soft iron gave under these conditions by far the greatest force, its inherent polarity being greater than that of steel. I have made numerous other experiments bearing upon the question of neutrality, but they all confirm those I have cited, which I consider afford ample evidence of the symmetrical arrangement of neutrality.

SUPERPOSED MAGNETISM.

Knowing that by torsion we can rotate or diminish magnetism, I was anxious to obtain by its means a complete rotation from north polarity to neutrality, and from neutrality to south polarity, or to completely reverse magnetic polarity by a slight right or left torsion. I have succeeded in doing this, and in obtaining strong reversal of polarities, by superposing one polarity given whilst the rod is under a right elastic torsion with another of the opposite polarity given under a left elastic torsion, the neutral point then being reached when the rod is free from torsion. The rod should be very strongly magnetised under its first or right-hand torsion, so that its interior molecules are rotated, or, in other words, magnetised to saturation; the second magnetization in the contrary sense and torsion should be feebler, so as only to magnetize the surface, or not more than one-half its depth; these can be easily adjusted to each other so as to form a complete polar balance of force, producing, when the rod is free from torsion, the neutrality as shown at B, Fig. 1. The apparatus needed is simply a good compound horse-shoe permanent magnet, 15 centimetres long, having six or more plates, giving it a total thickness of at least 3 centimetres, We need a sufficiently powerful magnet, as I find that I obtain a more equal distribution of magnetism upon a rod or strip of iron by drawit lengthwise over a single pole in a direction from that pole, as shown in Fig. 2; we can then obtain saturation by repeated drawings, keeping the same molecular symmetry in each experiment. In order to supply a slight elastic torsion when magnetizing rods or wires, I have found it convenient to attach two brass clamp keys to the extremities of the rods, or simply turn the ends at right angles, as shown in the following diagram, by which means we can apply an elastic twist or torsion whilst drawing the rod over the pole of the permanent magnet. We can thus superpose several and opposite symmetrical structures, producing a polar north and south as desired, greatly in excess of that possible under a single or even double magnetization, and by carefully adjusting the proportion of opposing magnetisms, so that both polarities have the same external force, the rod will be at perfect external neutrality when free from torsion.

FIG. 2.



If we now hold one end of this rod at a few centimetres distance from a magnetic directive needle, we find it perfectly neutral when free of torsion, but the slightest torsion right or left at once produces violent repulsion or attraction, according to the direction of the torsion given to the rod, the iron rod or strips of hoop-iron which I use for this experiment being able, when at the distance of 5 centimetres from the needle, to turn it instantly 90° on either side of its zero. The external neutrality that we can now produce at will is absolute, as it crosses the line of two contrary polarities, being similar to the zero of my electric sonometer, whose zero is obtained by the crossing of two opposing electric forces. This rod of iron retains its peculiar powers of reversal in a remarkable degree, a condition quite different to that of ordinary magnetization, for the same rod, when magnetised to saturation under a single ordinary magnetism, loses its evident magnetism by a few elastic torsions, as I have already shown; but when it is magnetised under the double torsion with its superposed magnetism, it is but slightly reduced by variations or numerous torsions, and I have found it impossible to render this rod again free from its double polar effects, except by strongly remagnetizing it to saturation with a single polarity. The superposed magnetism then becomes a single directive force, and we can then, by a few vibrations or torsions reduce the rod to its ordinary condition. The effects of superposed magnetism and its double polarity I have produced in a variety of ways, such as by the electro-magnetic influence of coils, or in very soft iron simply by the directive influence of the earth's magnetism, reversing the rod and torsions when held in the magnetic meridian, these rods when placed magnetic west showing distinctly the double polar effects. It is remarkable, also, that we are enabled to superpose and obtain the maximum effects on thin strips of iron from $\frac{1}{4}$ to $\frac{1}{2}$ millimetre in thickness, whilst in thicker rods we have far less effect, being masked by the comparatively neutral state of the interior, the exterior molecules then reacting upon those of the interior, allowing them to complete in the interior their circle of attractions.

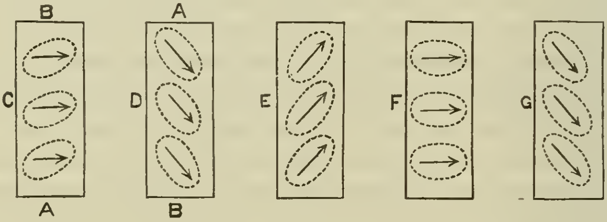
I was anxious to obtain wires which would preserve this structure against the destructive influence of torsion and vibrations, so that I could constantly employ the same wires without the comparatively long and tedious process of preparation. Soft irom soon loses the structure, or becomes enfeebled, under the constant to and fro torsions requisite where we desire a constant change of polarity, as described later in the magnetic bells. Hard steel preserves its structure, but its molecular rigidity is so great that we obtain but mere traces of any change of polarity by torsion. I have found, however, that fine cast steel, untempered, of the kind employed by watch makers, is most suitable; these are generally sold in straight lengths of 30 centimetres. Wires 1 millimetre in diameter should be used, and when it is desired to increase the force, several of these wires—say nine or ten—should be formed into a single rod or bunch. The wire as sold is too rigid to give its maximum of molecular rotation effect. We must, therefore, give it two entire turns or twists to the right, and strongly magnetise it on the north pole of the magnet whilst under torsion. We must again repeat this operation in the contrary direction, after restoring the wire to its previous position, giving now two entire turns to the left, and magnetising it on the south pole. On restoring the wire to its original place, it will be extremely flexible, and we may now superpose several contrary polarities under contrary torsions, as already described. The power of these wires, if properly prepared, is most remarkable, being able to reverse their polarity under torsion, as if they were completely saturated; and they preserve this power indefinitely if not touched by a magnet. It would be extremely difficult to explain the action of the rotative effects obtained in these wires under any other theory than that which I have advanced; and the absolute external neutrality that we obtain in them when the polarities are changing, we know, from their structure, to be perfectly symmetrical. I was anxious to show, upon the reading of this paper, some mechanical movement produced by molecular rotation, consequently I have arranged two bells that are struck alternately by a polarized armature put in motion by the double polarized rod I have already described, but whose position, at 3 centimetres distant from the axis of the armature, remains invariably the same. The magnetic armature consists of a horizontal light steel bar suspended by its central axle; the bells are thin wine glasses, giving a clear musical tone loud enough, by the force with which they are struck, to be clearly heard at some distance. The armature does not strike these alternately by a pendulous movement, as we may easily strike only one continuously, the friction and inertia of the armature causing its movements to be perfectly dead-beat when not driven by some external force, and it is kept in its zero position by a strong directive magnet placed beneath its axis. The mechanical power obtained is extremely evident, and is sufficient to put the sluggish armature in rapid motion, striking the bells six times per second, and with a power sufficient to produce tones loud enough to be clearly heard in all parts of the hall of the society. As this is the first direct transformation of molecular motion into mechanical movement, I am happy to show it on this occasion. There is nothing remarkable in the bells themselves, as they evidently could be rung if the armature was surrounded by a coil and worked by an electric current from a few cells. The marvel, however, is in the small steel superposed magnetic wire producing by slight elastic torsions from a single wire, 1 millimetre in diameter, sufficient force from mere molecular rotation to entirely replace the coil and electric current.

ELASTIC NATURE OF THE ETHER SURROUNDING THE MAGNETIC MOLECULES.

During these researches I have remarked a peculiar property of magnetism, viz., that not only can the molecules be rotated through any degree of arc to its maximum, or saturation, but that, whilst it requires a comparatively strong force to overcome its rigidity or resistance to rotation, it has a small field of its own through which it can move with excessive freedom, trembling, vibrating or rotating through a small degree with infinitely less force than would be required to rotate it permanently on either side. This property is so marked and general that we can observe it without any special iron or apparatus. Let us take a flat rod of ordinary hoop-iron, 30 or more centimetres in length. If, whilst holding this vertically, we give freedom to its molecules by torsions, vibrations. or, better still, by a few blows with a wooden mallet upon its upper extremity, we find, as is well known, that its lower portion is strongly north, and its upper south. If we reverse the rod, we now find it neutral at both extremities. We might here suppose that the earth's directing force had rotated the molecules to zero or transversely, which in reality it has done, but only to the limit of their comparatively free motion ; for if we reverse the rod to its original position, its previous strong polarity reappears at both extremities, thus the central point of its free motion is inclined to the rod, giving by its free motion great symmetrical inclination and polarity in one direction, but when reversed the inclination is reduced to zero.

In Fig. 3, D shows the bar of iron when strongly polarized by earth's magnetic influence under vibrations, with a sufficient force to have rotated its elastic centre of action. C shows the same bar with its molecules at zero, or transversal, the directing force of earth being insufficient without the aid of mechanical vibration to allow them to change. The dotted lines of D suppose the molecule to be in the centre of its free motion, whilst at C the molecules have rotated to zero, as they are prevented from further rotation by being at the extreme end of its free motion. If, now, we hold the rod vertically, as at C, giving neutrality, and give a few slight blows with a wooden mallet to its upper extremity, we can give just the amount of freedom required for it to produce evident polarity, and we have then equal polarity no matter which end of the bar is below, the centre of its free rotation here being perfect, and the rod perfectly neutral longituinally when held east and west. If, on the other hand, we have given too much freedom by repeated blows of the mallet, its centre of free motion becomes inclined with the molecules, and we arrive at its first condition, except that it is now neutral at D and polarized at C. From this it will be seen that we can adjust this centre of action, by vibrations or blows, to any point within the external directing influence. We can perceive this effect of free rotation in a limited space in all classes of iron and steel, being far greater in soft Swedish iron than in hard iron or steel. A similar phenomenon takes place if we magnetize a rod held vertically in the direction of earth's magnetism. It then gives greater polarity than if magnetized east or west, and if magnetized in a contrary sense to earth's magnetism, it is very feebly magnetized, or, if the rod is perfectly soft, it becomes neutral after strong magnetization. This property of comparative freedom, and the rotation of its centre of action, can be demonstrated in a variety of ways. One remarkable example of it consists in the telephone. All those who are thoroughly acquainted with electro-magnetism, and know that it requires measurable time to charge an electro-magnet to saturation (about $\frac{1}{15}$ of a second for those employed in telegraphy), were surprised that the telephone could follow the slightest change of timbre, requiring almost innumerable changes of force per second. I believe the free rotation

FIG. 3.



I have spoken of through a limited range explains its remarkable sensitiveness and rapidity of action, and, according to this view, it would also explain why loud-sounding telephones can never repeat all the delicacy of timbre that is easily done with those only requiring a force comprised in the critical limits of its free rotation. This property, I have found, has a distinct critical value for each class of iron, and I propose soon to publish researches upon the molecular construction of steel and iron, in which I have made use of this very property as a guide to the quality of the iron itself. The elastic rotation (in a limited space) of a molecule differs entirely from that known as mechanical elasticity. In perfectly soft iron we have feeble *mechanical* elasticity, whilst in tempered steel we have that elasticity at its maximum. The contrary takes place as regards *molecular* elasticity. In tempered steel the molecules are extremely rigid, and in soft iron its molecular elasticity is at its maximum. Its free motion differs entirely from that given it by torsion or stress. We may assume that a molecule is surrounded by continuous ether, more of the nature of a jelly than of that of a gas; in such a medium a molecule might freely vibrate through small arcs, but a rotation extending beyond its critical limit would involve a much greater expenditure of force.

The discovery of this comparatively free rotation of molecules, by means of which, as I have shown, we can (without in any degree disturbing the external mechanical elasticity of the mass) change the axes of their free motion in any direction desired, has led me into a series of researches which have only indirectly any relation with the theory of magnetism. I was extremely desirous, however, of finding an experimental evidence which in itself should demonstrate all portions of the theory, and the following experiment, I believe, answers this purpose. Let us take a square soft iron rod, 5 millemetres in diameter by 30 or more centimetres in length, and force the molecules, by aid of blows from a wooden mallet, as previously described, to have their centres of free motion in one direction; the rod will (as already shown) have polarity at both ends, when held vertically; but if reversed, both ends become completely neutral. If now we turn the rod to its first position, in which it shows strong polarity, and magnetize it whilst held vertically, by drawing the north pole of a sufficiently powerful permanent magnet from its upper to its lower extremity, we find that this rod, instead of having south polarity at its lower portion, as we should expect from the direction of the magnetization, is completely neutral at both extremities, but if we reverse the rod, its fullest free powers of magnetization now appear in the position where it was previously neutral. Thus, by magnetization, we have completely rotated its free path of action, and find that we can rotate this path as desired in any direction by the application of a sufficient directing power. If we take a rod as described, with its polarities evident when held vertically, and its neutrality also evident when its ends are reversed in the same magnetic field, we find that its polarity is equal at both ends, and that it is every way symmetrical with a perfect magnet. If we gradually reverse the ends and take observations of its condition through each degree of arc passed over, we find an equal symmetrical diminution of evident external polarity until we arrive at neutrality, when it has no external trace of inherent polarity, but its inherent polarity at once becomes evident by a simple return to its former position. Thus the rod has passed through all the changes from polarity to neutrality, and from neutrality to polarity, and these changes have taken place with complete symmetry.

The limits of this paper do not allow me to speak of the numerous theoretical evidences as shown by the use of my induction balance. I believe, however, that I have cited already experimental evidences to show that what has been attributed to coercive force is really due to molecular freedom or rigidity; that in inherent molecular polarity we have a fact admitted by Coloumb, Poisson, Ampère, De la Rive, Weber, Du Moncel, Weidermann and Maxwell; and that we have also experimental evidence of molecular rotation and of the symmetrical character of polarity and neutrality. The experiments which I have brought forward in this paper, in addition to those mentioned in my paper read before the Royal Society, will, I hope, justify me in having advanced a theory of magnetism which I believe in every portion allows at least experimental evidences of its probable truth.

Spanish Copper Tubes. — The Metallurgical Society of San Juan de Alcarez has succeeded in manufacturing excellent copper tubes without soldering, so as to be able to compete with all other manufacturers, both in quality and in price. The mode of manufacture is new, and application has been made for a patent.—*La Gaceta Industrial*, Jan. 25, 1883. C.

NATIONAL EXHIBITION OF RAILWAY APPLIANCES, CHICAGO, ILL.

At the last stated meeting the Institute kindly passed a resolution accrediting me as its representative to the National Exhibition of Railway Appliances, now being held at Chicago, with the special duty of looking after the electrical exhibits, and I purpose now to give you a very brief report of my observations.

First, then, the Exhibition is a success, as such, but financially it is not likely to profit its projectors. This is due to the fact that it did not secure the hearty support of the local press.

As is usual with exhibitions, everything was in a very incomplete state on opening day, and there was the usual struggle for space by late exhibitors. On my first visit to the building, I called upon the Secretary and Directors, and learned from them that the greater part of the work and responsibility had fallen upon two or three gentlemen and that the burden was much too heavy. This would account for much of the confusion in the installation, which appeared as late as the second week of the exhibition. I found it impossible to get even a list of the electrical exhibits, much less learn where they were located, and I therefore hunted them up, and am not yet certain that I saw them all.

Confining myself, then, entirely to electrical apparatus, and passing by the many large displays of machine tools, forgings, etc., made by Philadelphia manufacturers, I would classify the electro-magnetic apparatus on exhibition under the heads Railway Signals, Magnetic Brakes, Electric Lights, Electro-Motors, and General Electrical Supplies.

As the Franklin Institute is now preparing for an electrical exhibition, it might be well to consider early a question which has bothered the managers of the Chicago exhibition, and that is, What to admit and what to reject? One of the first remarks made by a visitor on entering the building is that there are many things there which do not seem to have any connection with railroads, such as type-writers, paper-hangings, etc. One exhibitor complained that he was not allowed to exhibit envelopes because, he said, they were largely used by railroad companies. The Secretary, however, told him that they had concluded to draw the line at envelopes.

At first glance it might seem that it would be difficult to secure for an electrical exhibition a sufficient variety of articles to make a respectable show, but electricity has within a few years invaded so many fields hitherto occupied by other agencies, that before another year is upon us it may be necessary to draw the line closely and exclude much that would occupy space to the detriment of more appropriate articles.

The experience at Chicago shows what has often been demonstrated in this city, that the interest is largely increased by showing everything in motion that is made to move. Instruments should be so shown as to demonstrate at a glance what they are made for; otherwise it may be difficult to make such an exhibition as the Franklin Institute Exhibition of 1884 a popular one. An electric motor which does not move tells no tale except to the expert, and a Leclanché cell so placed that its use is not apparent, might as well be a jar of pickles.

To return to the exhibits, my attention was first called to the various systems of automatic electric railway signals, of which I made a special study. Only two of these appear to have been well digested; and I may here remark that it is surprising how many inventors cudgel their brains to get up apparatus which is of no earthly use, because they have not duly considered the conditions under which the appliances must be used. Automatic signals to be of any value must cover every possible case; must provide for every position of trains; but the majority of those exhibited seemed to have been gotten up with the idea that the only danger to be guarded against was that a train might be overtaken by a following train or run into an open draw. Unless provision is made for every case which could by any possibility arise, there is no likelihood of any automatic system being adopted on any well-regulated railroad. This is only another illustration that the best inventions originate with the workmen and spring from the necessities of the case.

There are two general systems, one of which uses the railroad track for the electric circuit, and the other uses wires either carried on poles or in cables. The Union Switch and Signal Company, of Pittsburg, exemplifies the first, and the Hall Railway Signal Company, of Meriden, Conn., the second system, and each seems to have fairly compassed the problem of automatic signalling. Both are in practical operation on railroads in this country.

Messrs. Crandell & Strohm, of this city, exhibit an automatic block system in operation which does not throw up visible signals, but which is intended to operate by shutting off the steam and putting on the air-brakes whenever the train enters a block which is not clear. Other systems are exhibited which aim to accomplish the same result.

The perfection of the Westinghouse air-brake would seem to close the field against any brake operated by a different method. The use of this brake, however, has hitherto been confined to passenger trains or short stock trains. This leaves a field for a good magnetic brake for freight trains, and two very creditable brakes of this character were shown. Both are actuated by a dynamo upon the locomotive, and one supplements this by a storage battery in each car to operate the brakes when the car is separated from the locomotive. There are several practical objections to these brakes in their present state of development, but a thoroughly good magnetic brake may yet be perfected.

The electric light was represented by five different systems of arc and incandescence lights. We are all now so familiar with the arc lights that I may simply say that they were all very good and all claimed to be the best. I may say, however, that one system had many admirers, and its lights, which were scattered plentifully through the whole space, were complimented for their beauty and steadiness. The inventors of that system are our honored associates Messrs. Thomson and Houston. The incandescence lights of the Maxim, Edison, and Swan systems were in endless profusion and much admired.

Electric motors did not show up very well. The only style was the Weston dynamo used as a motor on the Field & Edison Electric Railway, and in another place to operate a centrifugal pump for a waterfall. Prof. Sylvanus Thompson says there is a great field for electric transmission of power, but if the inventions thus far made public are the best that our inventors have developed, we have not yet climbed the fence. So far as the public are concerned, the electric railway is a success; the people stand in line for a chance to ride on it. But at what expense of power is the motor and loaded car, weighing in all perhaps four tons, propelled? On investigation I found that an 18 horse-power engine was not equal to the task of moving the train, and the gates were shut against the public until the wires were connected with a 40 light dynamo run by a much more powerful engine. In like manner the dynamo which operated the pump was a 5 or 6 light machine run by a 40 light dynamo.

The improvements in dynamos are chiefly in the new regulators for reducing the power to correspond with the reduction in work performed.

The storage battery made no show and seems to have been withdrawn from the public for a time.

In conclusion I would say that although the display at Chicago is a fine one and well worth a visit, I think we do these things better in Philadelphia, and the Franklin Institute with its long experience and excellent organization will have no trouble in arranging an exhibition more extensive, more attractive, and much more valuable in its results.

E. Alex. Scott.

Photo-Zincography.—In the office of the French Minister of Public Works, charts and plans are prepared by a process of photo-zincography. A plate of commercial zinc is chosen which is free from defects. In order to cleanse it thoroughly it is rubbed with a stiff hair brush, which is dipped into a mixture of one-third sulphuric acid and two-thirds water. After this cleansing, which removes every trace of oxidation and grease, the plate becomes very brilliant, and it is rubbed fof some minutes by a cork dipped in powdered pumice stone. It is then washed and plunged, for ten or fifteen minutes, into a bath acidulated with three per cent. of nitric acid. The plate then has a dull look and shows a slight roughness under the microscope. After having carefully dried it, it is covered by a preparation composed of 10 litres of water and 500 grammes of crushed nutgalls. After boiling this preparation until it is reduced about one-third, it is cooled and filtered through linen; then are added 100 grammes of common nitric acid and 6 grammes of pure chlorhydric acid. After the preparation has been left in contact with the plate for some time it is washed and dried, and then coated with bitumen in the ordinary manner, and exposed to the light under the drawing which is to be copied. When the exposure is over, the plate is warmed slightly and developed with the addition of a liquid containing 5 per cent. of acetic acid. To facilitate the inking, it is well to apply to the lines some oil, which destroys their brilliancy and turns them gray. Then, after a careful drying, the bitumen is dissolved by benzine, and the plate is again dried. It can then be delivered to the printer, who submits it, without any precautions, to the customary operations of lithography for inking and printing.—*Bul. de la Soc. d'Encour.*, Jan., 1883. C.

Orange Peel.—A special application has lately been made of an article that has hitherto been thought nearly worthless. It is well dried in an oven, and then used for kindling fires, for which its essential oil admirably fits it.—*Gaceta Industrial*, March 10, 1883. C.

Constitution of the Sun.—In the third part of his discussion of the physical and mechanical constitution of the sun, Faye states that the solar refraction is insensible, and he has been able definitely to establish the fact that the mean depth of the spots is fully $\frac{1}{200}$ of the solar radius, or more than 2,000 miles. This power of penetration is not peculiar to the sun; it is found to a high degree in our own atmosphere. A cyclone, or a tornado, which begins in the region of the cirrus clouds, at a height of four or five miles, descends vertically to the ground; if in its course it meets a deep valley, it descends again until it touches the new soil, on which it manifests the same strength as upon an elevated plateau. On the sun the obstacle is not the soil; it is the specific lightness of the gases, which are drawn into layers of increasing density until the work of which the whirl is capable has been completely exhausted. In our cyclones and tornadoes, which draw only air, and not a gas which is specifically lighter than air, the air possesses nearly the same density as that of the surrounding medium; there is, therefore, only a feeble ascensional tendency. The atmospheric equilibrium is re-established without the return of the whirling air to the higher regions. It is evident that the case must be far otherwise in the sun, where the descending gas is hydrogen. This gas, superheated in the lower regions, will soon remount far above its point of original departure and above the chromosphere; that is to say, into the almost complete vacuum of the coronal region, giving place to that astonishing apparition of luminous protuberances, which the beautiful discovery of Janssen and Lockyer allows us to study daily on the sun's circumference. This hydrogen is often seen to fall back to the sun in different forms; sometimes in tongues of fire, imitating a sort of rain, at other times by a collective movement, as if by a slow subsidence. The chromosphere, which is receiving the materials of these protuberances, does not sensibly change its level. The circulation of the hydrogen is, therefore, mostly vertical and due to gyrations of different magnitudes in the photosphere. The formation of faculæ and pores, and the various other changes of the sun's surface, are all explained mechanically by the same gyratory movements. —*Comptes Rendus*, Feb. 5, 1883. C.

Color of Distilled Water.—M. Meyer, of Zurich, has devised the following experiment: He encloses by parallel panes of glass a tube 7·5 metres (39·37 feet) long and with an interior diameter of 4 centimetres (1·575 inches). This apparatus, being filled with distilled water and placed horizontally, on looking through it at a black ground in the sunlight it appears of a deep intense blue. If, on the contrary, gas light is employed, a green color is perceived.—*Les Mondes*, Jan. 13, 1883. C.

Deep Sea Explorations.—Twenty-five years ago, Thomas Bell wrote the last pages of a history of the British crustacæ. He thought that he had raised a lasting monument, and flattered himself that his successors could add little to the information which he had given. The facts which have been subsequently discovered have profoundly modified the ideas of naturalists. It was supposed that life is impossible in the depths of the sea, and that the waters are condemned to obscurity, solitude and immobility. The pressure of the water, the absence of light, the slowness of the renewal of the water, the want of algæ or other vegetable materials, and the experiments of Prof. Edward Forbes upon the diminution of animal life with increasing depth, in the Egean Sea, were supposed to prove that life cannot exist at a greater depth than 450 metres (492 yds.) When Captains Ross and Wallich found some animals upon their sounding lines, which had descended to a depth of more than a kilometre ($\frac{5}{8}$ of a mile), it was thought that they had either been entangled near the surface or that they had fallen to the bottom after their death. In 1860, the cable between Sardinia and Algiers was broken, and numerous animals were found upon the gutta percha insulating surface. M. A. Milne Edwards was consulted upon the subject, and he found conclusive evidence that they had been born and developed at a depth of more than two kilometres (1·243 miles.) These discoveries awakened great interest and led to the preparation of the steam cutter *Travailleur*, in 1880, for a scientific exploration of the sea depths. The cutter has been employed in each of the three past summers, in the Gulf of Gascony, on the shores of the Iberian peninsula, Corsica, Algiers and Morocco, in the Strait of Gibraltar and at the Canary Islands, yielding an immense number of animals which were previously unknown, many of which were drawn from depths of more than 5 kilometres (3·1 miles).—*Am. de Chim. et de Phys.*, Dec., 1882. C.

Generation of Inflammable Gases in the Diffusion of Beets.—In extracting sugar from beet roots by diffusion, gases are liberated which sometimes take fire and burn with a bluish flame. L. Chevron has analyzed the escaping gases and finds that they consist at first only of carbonic acid and nitrogen. After awhile hydrogen begins to appear, which seems to be due to an acid reaction of the beet juice upon the iron with which it is in contact. He thinks it would be impossible for the hydrogen to accumulate in sufficient quantities to produce an explosion, but the inevitable corrosion of the diffusives by the acid juice is an inconvenience which should be guarded against.—*Bul. de l'Acad. de Belg.*, 1883. C.

Amber.—Natural amber is distinguished from artificial amber, or from other materials to which it has some resemblance, by the following characteristics: Copal is yellow, and always of a uniform color. Amber, on the other hand, has usually different shades at its two extremities. Amber exhales an aromatic odor when rubbed on the palm of the hand. This is not the case with copal or with artificial amber. Amber, when covered with tallow, and held for some minutes over a flame, inclines to bend, Artificial amber and copal do not bend. Natural amber is always harder than artificial amber and copal. It is crushed with difficulty, and is not so easily affected by rubbing with a finger-nail. It may be cut, filed, sawed or polished, but cannot be welded like copal and artificial amber. Natural amber only melts at a heat of 400° (688°F.). Cigar holders of artificial amber melt as soon as the light of the cigar reaches them. Copal does not melt, but splits.—*Chron. Industr.*, Jan. 7, 1883. C.

OBITUARY.—BENJAMIN HOWARD RAND.

Benjamin Howard Rand, son of Benjamin and Eleanor Spurrier Rand, was born in Philadelphia, October 1st, 1827. His professional studies were begun in 1843, under the eminent Dr. Robert M. Huston, the then Dean of Jefferson Medical College; he subsequently attended the usual courses of lectures at Jefferson Medical College. In 1848 he received his degree of M.D. from that institution. During the last two years of his student life he was clinical assistant to Professors Mutter and Pancoast. In 1850 he was elected Professor of Chemistry in the Franklin Institute, holding that position until his resignation in 1864. Upon the foundation of the Philadelphia Medical College—an institution which ceased to exist in 1861—he was elected to the chair of chemistry, and from 1852 to 1864 he was secretary to the Academy of Natural Sciences. This latter office, as well as his professorship in the Franklin Institute, he resigned in 1864, to accept the chair of chemistry in Jefferson Medical College, from which he resigned in May, 1877, on account of ill health. He was elected a fellow of the Philadelphia College of Physicians in 1853, and a member of the American Philosophical Society in 1868. He was also a member of the American Medical Association.

Besides frequent contributions to scientific periodicals he has written "Chemistry for Students," 1 vol., pp. 259 (1855), "Elements of Medical Chemistry," 1 vol., pp. 420 (1863 and 1875), and also edited Metcalfe's "Caloric," 2 vols., 1859.

Dr. Rand has been for some years in failing health. He died on the 14th of February, 1883, at the age of fifty-five.

Franklin Institute.

HALL OF THE INSTITUTE, June 20th, 1883.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham in the chair. Present, 82 members.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held June 13th, 8 persons had been elected to membership.

He also reported under instructions from the Board, the following correspondence referred to the Institute, viz.:

OFFICE OF THE MAYOR OF THE CITY OF PHILADELPHIA,
PHILADELPHIA, June 7th, 1883.

To the Managers of the Franklin Institute of Philadelphia:

GENTLEMEN:—I enclose a copy of an ordinance passed by the Councils of this City and approved May 28, 1883, entitled "An ordinance to authorize the Mayor to appoint a Board of Experts to report on the present system of paving the streets of Philadelphia."

Your attention to this ordinance would be appreciated.

Your early reply will oblige

Yours respectfully,
SAMUEL G. KING,
Mayor of Philadelphia.

AN ORDINANCE

To authorize the Mayor to appoint a Board of Experts to report on the present system of paving the streets of Philadelphia, and to devise a better system.

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain*, That the Mayor of Philadelphia be, and he is, hereby requested to obtain from the American Society of Civil Engineers, the Engineer Corps of the United States Army, and the Franklin Institute of this City, the names of six engineers, two to be selected by each of the above bodies as eminent in their profession and with particular reference to their knowledge and experience of the best system of pavement for the streets of large cities, due regard being had to its healthfulness, economy, smoothness, durability, and drainage, and that from said six names, of two to be selected by each of the above bodies, his Honor the Mayor be, and he is, hereby requested to select one from each body, and to constitute the three so chosen a Board of Experts.

SEC. 2. The duty of this Board shall be to point out to Councils the defects of the present system of paving the streets of Philadelphia, and, in comparison with the advantages of the Belgian block system, to make a thorough and exhaustive report of the most durable and best pavement that can be devised by them for said streets, particular regard being had to its healthfulness, economy, smoothness, durability, and drainage, and estimating the probable cost of a better system.

SEC. 3. The compensation of the said engineers is not to exceed one thousand dollars, inclusive of all individual expenses.

Warrants to be drawn on item 3 of ordinance of June 21, 1882, for the repaving streets with Belgian blocks or other improved pavement.

Approved May 28, 1883.

On the motion of Mr. Hector Orr, seconded by Mr. J. E. Mitchell, it was

Resolved, That we duly appreciate the compliment implied in the request of our City Councils, and hereby authorize the Board of Managers to comply with the same without delay.

Mr. E. Alexander Scott, the accredited representative of the Institute at the National Exhibition of Railway Appliances at Chicago, presented a report which appears elsewhere in this issue of the JOURNAL. By invitation, Mr. Robert Grimshaw made some remarks on the mechanical features of that Exhibition.

The Secretary, on behalf of the Committee on Science and the Arts, reported by instruction that the Committee had recommended the award of the John Scott Legacy Medal and Premium to James Beecher, of Philadelphia, for his Improvement in the Manufacture of Hollow-Handled Cutlery; to Henry Whitall, of Philadelphia, for his Celestial Planisphere; and to Robert Hitchcock, of Watertown, N. Y., for his Improvement in Mechanical Lamps.

He also reported that the above recommendations had been duly advertised for three months, and that no objections had been offered thereto. The recommendations were thereupon taken up separately, and approved without dissenting vote, and the Secretary was instructed to notify the Committee on Minor Trusts of the Board of City Trusts of the action of the Institute.

The Special Committee to whom was referred the subject of preparing a memorial of Dr. Benjamin Howard Rand, made a report which was accepted and referred to the Committee on Publications.

Several other Special Committees reported progress, and were continued.

Mr. J. E. Mitchell next gave a description of a series of American grindstones which he is preparing for the United States National Museum at Washington, by request of Prof. Spencer F. Baird. Mr. Mitchell illustrated his remarks by the exhibition of a series of microscopic sections of sandstones, granites, and marbles with the lantern microscope. An abstract of Mr. Mitchell's remarks appears in the JOURNAL for August.

Mr. C. John Hexamer then followed with a paper, descriptive of a new system for the construction of malt mills in breweries, designed to protect those establishments against danger from explosion. Mr. Hexamer's paper has been referred for publication.

The Secretary's report included a description, with lantern illustrations, of Melville C. Smith's project for constructing an Arcade Railway underneath Broadway, New York; an account of Mr. Joseph Wharton's contributions to the metallurgical treatment of nickel, with an exhibition of a very complete suite of specimens and products; and the exhibition and description of a number of mechanical inventions, among which were the following: Martin A. Howell, Jr.'s cast-iron files, alleged to be much more durable than the ordinary steel file; a set of the metallic thermometers of the Auburndale Watch Co., Boston; A. Edwards' Mercury Seal Sewer Trap; the Climax Fire-extinguisher, manufactured by Joseph Neumann, of Philadelphia; the Michela Type Writing Machine, an extremely simple mechanism, printing phonetic characters, and which was said to be in use in reporting the proceedings of the Italian Senate; Improved Planimeters and Diagrammeters, shown on behalf of Mr. Oswald McAllister, of Philadelphia, etc.

The meeting was thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVI. SEPTEMBER, 1883. No. 3.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

STANDARD REAMERS FOR LOCOMOTIVE WORK.

By COLEMAN SELLERS.

[The following is the address delivered by Mr. Coleman Sellers before the Master Mechanics' Association at its recent convention in Chicago, on the subject of Standard Reamers, as reported by the *Railroad Gazette*:]

Mr. Coleman Sellers said: When appointed to report upon the subject of the taper for reamers for bolts used in locomotive work, and a system of gauges to correct and maintain the standard when worn, I hesitated for some little time before accepting the task. In our own practice taper bolts have not been used in the manner contemplated in the report, but I felt able to consider the subject impartially, and so accepted the task. A mechanical engineer is likely to be interested in what tends toward uniformity in shop practice. As the commission given to me calls for a consideration of the taper of the bolts used in locomotive work, in the first place, therefore, it presupposes that taper bolts are a necessity. This may be perfectly correct. In our own practice we divide bolts into classes, and our rule is in every case where a through bolt, that is bolt and nut can be used, a through bolt must be used. If a through bolt cannot be used, then, if possible use a stud bolt; and if that cannot be used, then as a last resort a tap bolt may be employed. The reason why the tap bolt is put last is because its nut is part and parcel of the machine itself. In the other two cases we have the nut upon the bolt or the nut upon the stud, and in the third case we have the wear-and-tear of a nut forming part of the machine. Through bolts are of two kinds, loose-fitting and tight-fitting, or "body-bound." Loose fitting bolts which are generally black or unfinished, are put into holes $\frac{1}{16}$ of an inch larger than the bolt itself. It is possible in fastening a machine together, whether part of a machine tool or part of a locomotive, to use black bolts in combination with body-bound bolts, the latter serving as dowel pins to prevent side motion. With body-bound bolts, it is customary among machine builders to use a straight reamer and make a straight hole, and turn the bolt straight to gauge, so that it will fit its place. If the bolt is made perfectly straight and fitted into a reamed hole, it is an unsettled question as to how tight it should fit. In practice, the longer and larger the bolt, the nearer it is made to gauge size. A bolt so sized by gauge, as in a short length, to be a running fit, will seem very tight in a deeper hole. The difference between a tight and a loose fit is somewhere in the neighborhood of the ten-thousandth part of an inch. It is held by many locomotive builders, that the use of straight bolts is objectionable on the score that if they are driven in as tight as they say they should be, there is much difficulty in getting them out; that when they are taken out of a hole into which they have been driven two or three times they become too loose, and there is no means of making them tighter, resulting in their being discarded at the expense of making other larger bolts to be introduced in their place. There is no great difficulty about making two bolts of commercially the same size, but there is a vast difference between absolute accuracy and commercial accuracy. Absolute accuracy is a thing that is not attainable. Mr. Bond, from the Pratt and Whitney Company, who is present, knows this just as well as I do. I know how diligently the Pratt & Whitney Company have labored to approach absolute accuracy in their gauges, and how far they are in their own estimation from reaching that point, although they have reached a wonderful degree of perfection. What we have to strive for, then, is commercial accuracy. What system can we adopt that will enable workmen of limited capacity to do work that shall be commercially accurate? The taper bolt, for certain purposes, presents very decided advantages when considered in this relation. I have said that bolts may be made practically of the same diameter. Holes cannot be made accurately of the same diameter by reamers. Each reamed hole is only an approximation to correctness. We have here (showing) an ordinary fluted reamer.

A reamer is intended to produce a straight hole, but you will all admit that having passed this reamer once through a hole, the reamer must be slightly worn. The next time you pass it through it is a little more dull, and each time it is worse, the hole made by it must become smaller. There have been many attempts to produce a reamer which will be adjustable. Thanks to the gentlemen who are now making such tools a specialty, there now has been added a very useful tool to the machine shop. Here is a reamer made by the Betts Machine Company, of Wilmington. In this the straight cutter blades are made wedge-shape on their back edge, and are seated in wedge-shaped or taper grooves, to match the taper of the blades; these blades can be set to fit a standard gauge.

Fig. 1.

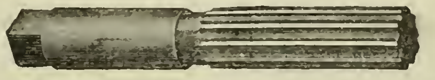
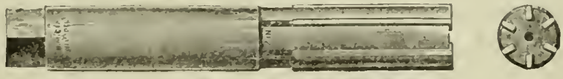


Fig. 2.



This will enable us to make and maintain a commercially uniform hole in our work. But the successful use of a reamer of this kind depends upon the drills that precede the reamer, being made as nearly right to size as possible; in other words, that the reamer has as little work given it to do as possible. The less you give a reamer to do the longer it will last and the longer it will maintain its size. The question of tapered bolts involves at once this difficulty, that we have to drill straight holes; then the tapered reamer is obliged to take out all the metal that must be removed in order to convert a straight into a tapered hole. The straight hole reamer is maintained to size longest by taking out the least amount of metal. Hence it follows that the tapered reamer would be the nearest right for durability, which also would take out the least amount of metal. A short reamer like that (see Fig. 1) will answer for a hole of a very considerable depth. It is only necessary that the length of the reamer shall be three or four times its own diameter. The Pratt & Whitney Company has furnished me with reamers made for the Baldwin Locomotive Works. These are reamers that are to do precisely the work that we now have under consideration. They are to make a tapered hole, but you will observe the difference in lengths between the two. The straight $1\frac{1}{4}$ inch reamer is say 4 inches long in the blades, the taper reamer is say 20 inches long.

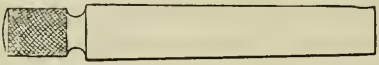
Let us now consider the question of amount of the taper. No round piece of iron can go into a round hole in another piece of iron unless it is smaller than the hole into which it is intended to go. If it is in any degree larger it must compress the plug itself, or stretch the material that is around the hole. So if we adopt a tapered bolt we cannot fix upon a certain uniform distance that each and all bolts shall stand out before we begin to drive them. If the material is to be compressed, you will admit that there is a great deal more material capable of being compressed in a piece of large diameter than in one of small diameter. Metal is elastic; as long as we keep within the elastic limit of the metal, we are safe in assuming that it acts like a spring. In the large bolt and in the small one we have springs of different lengths. In the large bolt we have a long spring and in the small one we have a short spring. If we drive a bolt into a large piece of iron, it is the bolt which we compress; therefore the larger the bolt, the more the pressure we can give it to produce the desired result. Therefore if we adopt any fixed taper for our bolts, we will have to use discretion, or go into an elaborate series of experiments, as to how far we should let our bolt-head stand away from the work before we begin to drive it Now I find varying practice obtaining in locomotive establishments. There are some builders of locomotives (I mean connected with railroads) who put the straps upon their stub ends with tapered bolts, but do not use tapered bolts in any other parts of the structure. The Baldwin Works use tapered bolts wherever they require body-bound bolts. They make an universal taper of $\frac{1}{16}$ inch to the foot in diameter. Suppose it is an inch bolt we are dealing with, and an inch bolt 12 inches long, and we started with an inch, and we ran it up to a taper of $\frac{1}{16}$ inch, it would result in this being $\frac{1}{16}$ larger under the head than at the point.

They make all their bolts which are under 9 inches in length $\frac{1}{16}$ inch larger under the head than the name of the bolt. Thus a $\frac{3}{4}$-inch bolt is made $\frac{13}{16}$ under the head, provided that bolt is 9 inches long or under. Anything over 9 inches long is made $\frac{1}{8}$ inch larger under the head and still made a taper of $\frac{1}{16}$ inch to the foot. Most of the bolts used in locomotives are under 9 inches long. I have been shown bolts 20 to 22 inches long that were made a taper of $\frac{1}{16}$ inch to the foot, and those were the bolts that fastened the saddle and the frame together; practically, however, the great bulk of bolts that are used about locomotives are those which are less than 9 inches in length and come under the category of $\frac{1}{16}$ inches to the foot, and $\frac{1}{16}$ inch larger under the head than the name of the bolt. A locomotive builder now in this city tells me that the specifications of engines submitted to him in many cases name the required tapers for all bolts—some call for $\frac{1}{8}$ inch to the foot. The Pennsylvania road calls for $\frac{3}{32}$ inch to the foot. All Baldwin locomotives are $\frac{1}{16}$ inch to the foot. He tells me that the majority of the specifications, if they do prescribe the taper at all, ask for $\frac{1}{16}$ with the exception of the Pennsylvania. The advantage of the $\frac{1}{16}$ would seem to lie in the fact that a bolt headed in the ordinary manner can be made to fill the requirements, provided it is made of iron $\frac{1}{8}$ inch larger than the name of the bolt. For the purpose of discussing this question at the present time it would be as well for us merely to adopt some taper which I should say might be $\frac{1}{16}$ inch to the foot, and carry that through the system of gauges I propose to show you, so as to enable us to judge whether it is a practical system, and how far we can use it. If we shall decide that bolts should be tapered, for the reason that when a tapered bolt is driven into its place it can be very readily knocked loose, if that tapered bolt, when it is in, proves to be too loose, we have merely to turn out under the head and drive it a little further. These are arguments in favor of the tapered bolts, and show why it is an advantage to use them, their use rendering it easier to repair work that is secured by them than work that has straight bolts. If we adopt a tapered bolt, and let us say with a taper of $\frac{1}{16}$ inch to the foot, it is then well to make up our mind how we are going to make bolts, and bore the taper holes in a commercial manner; in other words, so that it can be brought into what we call the interchangeable system.

No matter what taper is adopted, either by general consent uniform among the shops and the railroads or different in any of them, yet there is always the same need for a system of gauges to carry out the principle in each shop. The Baldwin Locomotive Works, having used the taper system for many years and considering it essential, long ago perfected a system of gauges which seem to me to meet the case. This system may be explained as follows:

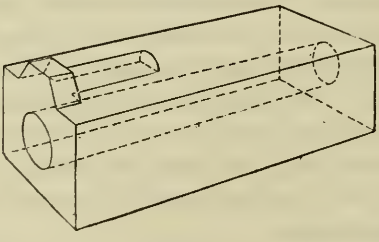
For each diameter of bolt, and for all bolts under 9 inches in length, they keep in their storeroom steel plugs ground to a taper of $\frac{1}{16}$ inches to the foot in length, and each standard plug is made at its largest end exactly $\frac{1}{16}$ inch larger in diameter than the name of the bolt it represents. Thus for a one-inch bolt the standard plug will be on the taper part say 6 inches long, and one end of it will be $1\frac{1}{16}$ inch diameter, and the other end will be $1\frac{1}{32}$ inch in diameter, a convenient milled handle being provided beyond the large end of the gauge, as in Fig. 3.

Fig. 3.



To this standard plug is fitted a ring gauge or female gauge of any convenient external form, which is in length the same as the taper part of the standard plug; so that when the hole and the plug are clean and dry, the one should just fit and fill the other and come flush at the upper end. These plugs and rings are to be retained in the storeroom as standards to try other gauges by. It is stated that the large majority of bolts used on a locomotive and made taper, can on the taper of $\frac{1}{16}$ inch to the foot, be driven home if the size of the bolt and hole is such as will cause the head of the bolt to stand above the top of hole one-eight of an inch, and when such a bolt has been driven home it will have compressed the bolt or stretched the metal into which it has been driven to the amount of ·0065 inch, and the fit will be almost as tight as are car wheels forced on to their axle in the usal manner. The gauges used by the workmen at the turning lathes for bolt work are made of cast-iron similar to the gauge described in connection with the steel plug, but are rectangular, so as to rest well on the lathe bed in a handy position for trial, and on each one of these gauges is cast the representation of one-half of the kind of bolt it is used for, as for example one for hexagon-head bolts, and one for countersunk-head bolts. (See Fig. 4.)

Fig. 4.



The bench or rather lathe, gauge for an inch bolt may be, say 6 inches long and $2\frac{1}{4}$ inches square; the same sized casting, in fact, may be used for several sizes of bolts. These lathe gauges are reamed to such a size that the standard plug in the storeroom will be flush with the top of the gauge, precisely as is the standard ring in the storeroom on the same plug. Bolts turned taper must fit this gauge with the head just touching the top of gauge, and without rattle or shake over the length of the gauge. The reamers used for tapering the holes in the shop should be not only long enough to enter the hole drilled and tapered to the required size, but there should be several inches left at the large end to allow for redressing; thus a one-inch reamer should be one-inch in diameter at its small end, at one foot from small end it should be $1\frac{1}{16}$ inches in diameter, and if beyond this it continues at the same taper, say three inches, it should measure $1\frac{5}{64}$ inches in diameter at its largest end. Such a reamer may be reground until its largest diameter has been reduced to the standard size. These reamers are guarded at their upper end by a collar driven on and covering the entire unused part of the reamer, which collar can from time to time be dressed off at the lower end to gauge, to keep the size correct. To adjust the reamers there are kept in the storeroom a set of rings, one for each size of bolt, which are so sized that the standard plug does not enter flush, but stands out one-eight of an inch. It is well, too, to retain in the storeroom reamers not guarded at the large end, which can be used from time to time in retapering the gauges in use at the shop. Figuring or lettering on the gauges should not be on the upper end, as that part in readjusting requires to be turned away.

The same system of gauges for the bolts that are $\frac{1}{16}$ inch larger under the head than the name of the bolt, and which bolts are 9 inches long or under, can be carried out in making the bolts that are $\frac{1}{8}$ inch larger under the head and are 9 inches long. The outfit requird, therefore, is for the storeroom: one plug gauge and one female gauge to match for each size of bolt, and for each kind of bolt, whether under or over 9 inches long; one ring or female gauge for the adjustment of the reamers, with the hole as much smaller than the bolt as will give the proper compression, and one standard reamer for the adjustment of the gauges. In the shop the gauges are female for the bolts and the guarded reamers for making the holes.

The taper bolt system calls for the use of two lathes to make each bolt, one to turn the cylindrical apart for the screw thread and to square up under the head, the other lathe set to a uniform taper, not by the setting over of the head, but by means of some good former attachment, that will insure uniformity of taper regardless of the length of the bolt. In the first lathe the gauges used may with advantage be such as these very fine snap gauges made by the Pratt & Whitney Co. of drop-forged steel, or those made by the Betts Co., of Wilmington Delaware. (Both makes of snap gauges were shown.) With a double ended gauge the cylindrical end of the bolt can be made ready for the screw lathe or the bolt cutter, and with the larger gauge $\frac{1}{16}$ larger, the diameter under the head can be brought to size, and this sized part can be utilized to start the taper in the taper lathe, either starting the cut at that part or setting the tool to a stop screw in the rest at the large diameter, backing off and entering the cut at the small end of the bolt, and turning up toward the head. In practice it is found that the size and taper can be readily hit, and the gauge has very little wear from excessive use and repeated trials. When turned to size the bolt should fit the taper gauge with no shake and the head just touching the end of the lathe. The inspector in the bolt storeroom should also examine the bolts with the taper gauge before putting them into stock. By means of the standards in the toolroom the gauges for the lathe and the taper reamers can be kept to size. There are now to be had very convenient tools arranged for grinding the cutting edges of reamers to any required taper.

It is the practice with some users of taper body-bound bolts to only taper the holes to a depth equal to the thickness of the thinnest piece to be secured. As for example, where the braces from the boiler are attached to the thick frame, they will ream the hole taper through the brace foot and for an equal depth into the frame, and while the bolt is made tapered down to the thread it will not fit the hole anywhere below the taper part of the hole. If a drill $1\frac{3}{64}$ inches diameter be used to drill the hole for an inch bolt, and the drilled hole be reamed out to near $1\frac{1}{16}$ at the top, the taper will be for a depth of 3 inches only; quite enough bearing to hold a foot $1\frac{1}{2}$ inches thick in place.

Having described the system of gauges to you and explained some of the uses and advantages of taper bolts under certain conditions, I do not feel prepared to report in favor of any particular taper for such bolts. The question of uniformity of taper in the body of bolts, while it is of importance as tending to interchangeability, yet involves more important considerations than in the change of the threads used on the bolts themselves. The taper hole for the bolt in any machine becomes part of the machine. The bolt itself, a movable piece, may be put into such a hole with any one of a dozen kinds of threads cut on its end. The taper that has been already adopted in any shop or on any road requires that all future work shall conform to it.

If the Pennsylvania Railroad and all its branches have adopted $\frac{3}{32}$ it is folly to ask them to change it to $\frac{1}{16}$ inches because their own connections are large enough to make them independent of almost any other corporation, and the need of absolute uniformity in their work would cause them to stick to that particular taper. Any of you having five, six, seven, or two or three hundred locomotives must make up your minds what you will do. When we changed the standard for screw threads, a screw thread was adopted which had a manifest advantage. It is easy to adopt a screw thread. A bolt with any kind of screw thread can be used on any machine. But once having adopted a taper for the body of bolts on a road it is very difficult to make a change, and whether it is wisdom for this Association to say that any particular taper shall be the standard, is a question that I am entirely unable to answer. Therefore, I am unwilling to recommend any taper to you, and only present the facts; but I will say that $\frac{1}{16}$ inch is enough. The less taper you have the less material you have to cut away. But to say that $\frac{1}{16}$ is preferable to $\frac{3}{32}$ is folly because no human being could feel the difference. If a bolt has 5 degrees taper it will set well; if it has 6 or 7 degrees it may jump out. Five degrees is about the angle of friction for iron. Five degrees would be an absurd angle for a taper. Any taper, then, that will hold the bolt when driven in, will answer the purpose. I think that the presentation which I have made, showing you a system of gauges which is already in use by those who have had long experience, may enable you to discuss the matter, so as to arrive at some conclusion as to whether you will adopt a uniform taper or whether you will let things go as they are. Nothing is more desirable than an interchangeable system; and while it is undoubtedly advantageous to make all parts of machines on the interchangeable system, yet in the matter of making holes to size there is a very good illustration of the difficulty enumerated taken from work with which I am familiar. In making turning lathes, the part that the longest resisted this uniformity was the sliding spindle of the deadhead. Spindles may be made very close to size, but not so close that each spindle must be fitted to place in the hole ground out to receive it, this for the reason that any shake or looseness other than which will permit freedom of motion is detrimental, and it was not until the plan was adopted of arranging conical self-centering clamps to each end of the bearing of the dead-head spindles that such spindles could be made to gauge, and thus added to the list of the interchangeable parts of the machine.

In conclusion, it seems to me that the consideration of the uniformity of taper should be entered upon with caution; but from what I have presented to you as bearing on the facts of the case, you must be quite as well prepared to debate the question as if I had urged the adoption of any particular standard taper. If you do not see fit to consider the question, the system of gauges as used by the Baldwin Locomotive works will enable those who desire to systematize their taper bolt making, and to carry it to a reasonable degree of uniformity in their shops.

ON THE SCREW PROPELLER.

By Jas. N. Warrington, M. E. (Stevens.)

The following pages are confined mainly to a discussion of the principles involved in the action of the screw propeller, and the conditions of maximum efficiency.

In part I the writer has endeavored to present the most advanced views on the subject, with reliable formulæ for design.

Part II contains an original mathematical scheme for the design of a propeller, with a discussion of efficiency.

I.—DISCUSSION OF THE ACTION OF THE SCREW PROPELLER.

The action of the screw propeller was formerly considered to be that of a screw in a nut. The slip was taken as the yield of a solid cylinder of water having a diameter equal to that of the wheel.

A truer conception of this action has come to be accepted at the present day. The late Dr. Froude was the first, I believe, to consider the action as that of a set of oblique surfaces which do not, and in fact should not, drive a solid stream. Had the propeller been developed from the windmill instead of the Archimedian screw, the principles of its action might perhaps have been earlier understood.

If we follow out the blade from the root to the tip, we see that the pitch angle grows smaller, so that the yield of the water is more nearly in the line of the ship's motion at the tip than near the boss. So far as this is concerned, then, the tip of the blade is the most efficient part.

But fluid friction varies nearly as the square of the velocity. At the periphery, therefore, the frictional loss will be greatest; and we will find that the most efficient part of the blade is at some intermediate point.

Froude finds the pitch angle, or angle between the blade and an athwart-ship plane, to be 45° for maximum efficiency. His discussion* is limited to a flat surface having a rectilinear motion. For such a surface the pressure is

$$P = p\,A\,v^2 \sin.\,\theta \qquad (1)$$

in which $p =$ a constant, $A =$ area of surface, $v =$ velocity of surface through the water, $\theta =$ angle between the plane and the line of motion. The value of p is about 1·7. The friction is

$$F = f\,A\,v^2 \qquad (2)$$

in which $f = 0{\cdot}008$ for a unit of surface of both face and back of blade.

To investigate the conditions of maximum efficiency let $A\,A^1$ represent a plane having a transverse velocity $A\,B$. Let $B\,C =$ speed of ship, and $C\,D =$ speed of slip. Then will $A\,C$ represent the motion

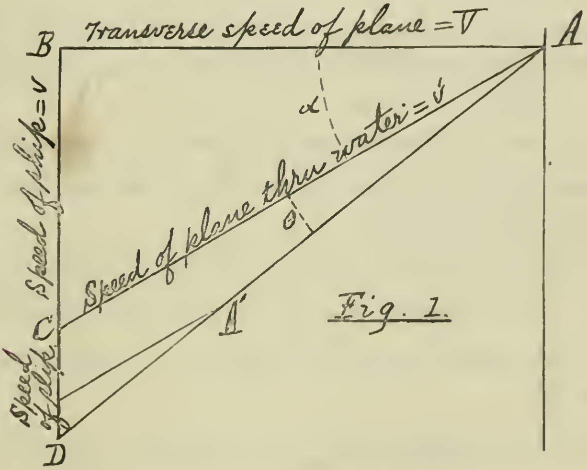


Fig. 1.

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* Transactions of the Institution of Naval Architects, 1878, vol. 19, p. 47.

of the plane through the water, both in direction and in velocity; $\frac{D\ C}{B\ D}$ = slip ratio, θ = slip angle, $\alpha + \theta$ = pitch angle. Then by equations (1) and (2) and the figure we have

$$P = p\ A\ V^2 \sec.^2 \alpha \sin. \theta \tag{3}$$

and

$$F = f\ A\ V^2 \sec.^2 \alpha \tag{4}$$

The effect of P in the line of the ship's motion is $P \cos. (\alpha + \theta)$; but from this must be deducted the longitudinal component of the surface friction, which is $F \sin. \alpha$. Thus the net force available for propulsion is $P \cos. (\alpha+\theta) - F \sin. \alpha$. This must equal the ship's resistance, R. Hence we have

$$R = P \cos. (\alpha+\theta) - F \sin. \alpha \tag{5}$$

The effective work done is that employed in overcoming the ship's resistance with the ship's actual speed. Call this work U_e. Then

$$U_e = R\ v = R\ V \tan. \alpha \tag{6}$$

Making the requisite substitutions and putting k for $\frac{f}{p}$ we have

$$U_e = p\ A\ V^3 \sec.^2 \alpha \tan. \alpha \left[\cos. (\alpha+\theta) \sin. \theta - k \sin. \alpha\right] \tag{7}$$

The gross work done is the transverse component of P plus the transverse component of surface friction, each acting with a speed, V. Call the gross work U_g; then

$$U_g = p\ A\ V^3 \sec.^2 \alpha \left[\sin. (\alpha+\theta) \sin. \theta + k \cos. \alpha\right] \tag{8}$$

In terms of v, the ship's speed, instead of V, the transverse speed of the plane, U_e and U_g become

$$U_e = p\ A\ v^3 \operatorname{cosec.}^2 \alpha \left[\cos. (\alpha+\theta) \sin. \theta - k \sin. \alpha\right] \tag{9}$$

$$U_g = p\ A\ v^3 \operatorname{cosec.}^2 \alpha \cot. \alpha \left[\sin. (\alpha+\theta) \sin. \theta + k \cos. \alpha\right] \tag{10}$$

But U_e also equals $R\ v$, and the value of A necessary to maintain propulsion is

$$A = \frac{R}{p\ v^2 \operatorname{cosec.}^2 \alpha \left[\cos. (\alpha+\theta) \sin. \theta - k \sin. \alpha\right]} \tag{11}$$

whence

$$U_g = R\ v \cot. \alpha\ \frac{\sin. (\alpha+\theta) \sin. \theta + k \cos. \alpha}{\cos. (\alpha+\theta) \sin. \theta - k \sin. \alpha} \tag{12}$$

Then the efficiency is

$$E = \frac{U_t}{U_g} = \tan.\, a \; \frac{\cos.\,(a+\theta) \sin.\,\theta - k \sin.\, a}{\sin.\,(a+\theta) \sin.\,\theta + k \cos.\, a} \qquad (13)$$

There will be no appreciable error in assuming $\sin.\,\theta = \theta$ and $\cos.\,\theta = 1$. With these substitutions equation (13) becomes

$$E = \tan.\, a \; \frac{\theta \cos.\, a - (\theta^2 + k) \sin.\, a}{\theta \sin.\, a + (\theta^2 + k) \cos.\, a}$$

$$= \tan.\, a \; \frac{\theta - (\theta^2 + k) \tan.\, a}{\theta \tan.\, a + (\theta^2 + k)} \qquad (14$$

The two differentiations of this equation give respectively the following values of θ and $\tan.\, a$ as the conditions of maximum efficiency:

When θ varies independently, $\theta = \sqrt{k}$.

When $\tan.\, a$ varies independently, $\tan.\, 2\, a = \frac{\theta}{\theta^2 + k}$

$$\text{or } \tan.\, a = \sqrt{1 + \left(\theta + \frac{k}{\theta}\right)^2} - \left(\theta + \frac{k}{\theta}\right)$$

$$\text{and } \tan.\,(a+\theta) = \frac{\sqrt{\theta^2 + (\theta^2 + k)^2} - (\theta^2 + k) + \theta \tan.\,\theta}{\theta - \theta \tan.\,\theta \left[\sqrt{\theta^2 + (\theta^2 + k)^2} - (\theta^2 + k)\right]}$$

Substituting $\theta = \sqrt{k}$, we have

$$\tan.\,(a+\theta) = \frac{\sqrt{1 + (2\,\theta)^2} - 2\,\theta + \tan.\,\theta}{1 + 2\,\theta \tan.\,\theta - \tan.\,\theta \sqrt{1 + (2\,\theta)^2}}$$

Now observing that when θ is small $\tan.\,\theta$ does not exceed θ by $\frac{1}{3\,\theta^3}$, so that when $\theta =$ say $\frac{1}{5}$, or just exceeds 10°, the difference between the arc and the tangent is less than $\frac{1}{375}$, we may put $\tan.\,\theta = \theta$; and since within the same scale of approximation $\sqrt{1 + (2\,\theta)^2} = 1 + (2\,\theta)^2$, we have

$$\tan.\,(a+\theta) = \frac{1 - \theta + 2\,\theta^2}{1 - \theta + 2\,\theta^2 - 2\,\theta^3}, \text{ or in effect } = 1.$$

Thus in all cases where the due relation between θ and k, $[\theta = \sqrt{k}]$, is maintained so as to secure maximum efficiency, the actual pitch angle which will give the maximum efficiency is 45°.

Froude shows that the maximum efficiency attainable is 77 per cent. The efficiency of a screw cannot be so great as this, since only one region of the blade can have the most effective pitch angle.

We see from this discussion that small slip does not mean high efficiency. The pitch angle at the centre of effort of the blade should be 45°. Hence, if the blade is wide at the tip, it should have a coarse pitch; and if it is narrow at the tip it should have a fine pitch, the object being to make the most efficient part of the blade do the most work.

The blades should not interfere with each other in their action. The fraction of the circumference occupied by the blade when they are projected on an athwart-ship plane, must not be greater, according to Cotterill*, than 1·18 sin. a cos. a, or more probably less, else the action of the blades will interfere with each other. In this, a is the pitch angle.

It is evident, then, that the action of the screw propeller in its most efficient working, does not involve the sternward projection of a solid stream, and hence all formulæ based upon such an assumption are inapplicable. But at the same time it is to be observed that it is by the sternward projection of the water that the vessel is impelled, and the nearer this approaches a solid stream the less becomes the loss by friction; or, in other words, the frictional loss is smaller, as the blades become shorter and wider, provided they are not so wide as to cause interference of action.

For the common screw of uniform pitch we have the following elementary relations. Let $a =$ pitch angle.

Then $$\tan. a = \frac{\text{pitch}}{\text{circumference}}$$

Speed of wheel = revolutions × pitch.

For the helicoidal area when the screw is limited by planes parallel to each other and perpendicular to the axis, we have the following.

The equations of a helix are† $x = r \cos. \varphi$; $y = r \sin. \varphi$; $z = k r \varphi$ in which $r =$ radius; $k = \frac{\text{pitch}}{\text{circumference}}$; $\varphi =$ angle at the centre subtended by the projection on a plane perpendicular to the axis.

Let l represent the variable length of the helix; then

$$d\,l = \sqrt{d\,x^2 + d\,y^2 + d\,z^2} = r\,d\,\varphi\ \sqrt{\sin.^2 \varphi + \cos.^2 \varphi + k^2}$$
$$= r\,d\,\varphi\ \sqrt{1 + k^2}$$

and $$l = r\varphi\sqrt{1 + k^2} + (C_1 = 0)$$

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* *Engineering*, vol. xxvii, p. 385.

† Price's Calculus, vol. i, p. 451.

If we let S represent the area we will have approximately,

$$S = \int l\,d\,r = \varphi \int_{r_2}^{r_1} r\,d\,r \sqrt{1 + \frac{\text{pitch}^2}{4\,\pi^2\,r^2}}$$

$$= \varphi \int_{r_2}^{r_1} d\,r \sqrt{r^2 + \frac{\text{pitch}^2}{4\,\pi^2}}$$

Integrating

$$S = \varphi \left[\frac{r}{2}\sqrt{r^2 + \frac{\text{pitch}^2}{4\,\pi^2}} + \frac{\text{pitch}^2}{8\,\pi^2} \text{ hyp. log.} \left\{ r + \sqrt{r^2 + \frac{\text{pitch}^2}{4\,\pi^2}} \right\} \right]_{r_2}^{r_1}$$

r_1 and r_2 being the radii of the periphery and boss respectively. We may put for φ its value in terms of z, the fore and aft length of the blade,

$$\varphi = \frac{z}{k\,r} = \frac{2\,\pi\,z}{\text{pitch}}$$

For the projection on an athwart-ship plane we have, letting $A =$ the total projected area and $N =$ the number of blades,

$$A = N\varphi \int_{r_2}^{r_1} r\,d\,r = \frac{N\varphi}{2}\left(r_1^{\,2} - r_2^{\,2}\right) = \frac{N\pi\,z}{\text{pitch}}\left(r_1^{\,2} - r_2^{\,2}\right)$$

A large majority of the propellers in use at the present day have an increasing pitch, either from the leading to the trailing edge, or from the boss to the periphery. The object of the former is to avoid, or, at any rate, to lessen, the shock at the leading edge, while the purpose of the latter is to move the centre of effort further from the boss to a more efficient part of the blade. I am indebted to Professor R. H. Thurston for the following method of deducing the equation of the curve of the developed screw of axially increasing pitch:—

Let α = angle of initial pitch.
P = initial pitch in feet.
P' = terminal pitch in feet.
$D = P' - P$ = difference of pitches.
C = circumference of screw disk.
K = fraction of circumference occupied by projection of one blade on screw disk.
x and y = coördinates.

As the curvature increases uniformly we have the condition,

$$\frac{dy^2}{dx^2} = \varepsilon \qquad (1)$$

$$\frac{dy}{dx} = \varepsilon x + b \qquad (2)$$

in which ε and b are constants to be determined by values assigned for anterior and posterior pitch.

When $x = o,\ \frac{dy}{dx} = tan.\ a = b = \frac{P}{C}$

When $x = K\,C,\ \frac{dy}{dx} = \frac{P'}{C}$

$$a = \frac{P' - P}{K\,C^2} = \frac{D}{K\,C^2}$$

Now equation (2) becomes

$$\frac{dy}{dx} = \frac{D\,x}{K\,C^2} + \frac{P}{C}$$

Integrate and determine constant by the principle that when $x = o$, $y = o$

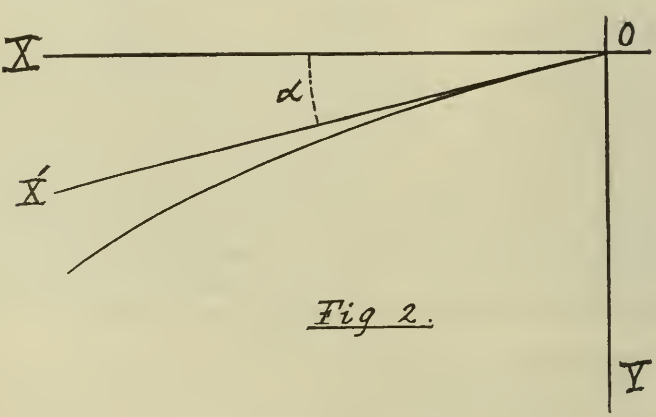

Fig 2.

$$y = \frac{D\,x^2}{2\,K\,C^2} + \frac{P\,x}{C} \qquad (3)$$

Now change the axis of X so that it shall be a tangent to the curve at the origin.

$$y = y' + x'\ sin.\ a\,;\ x = x'\ cos.\ a.$$

Let $l = \sqrt{C^2 + P^2}$; sin. $a = \frac{P}{l}$; cos. $a = \frac{C}{l}$

Substituting these values

$$y + \frac{Px}{l} = \frac{D\,x^2\,C^2}{2\,K\,l^2\,C^2} + \frac{Px}{l} \tag{4}$$

$$y = \frac{D\,x^2}{2\,K\,l^2} \tag{5}$$

in which $Kl =$ distance from anterior to posterior edge. Make $m =$ total number of ordinates and $n =$ number of ordinates from o, and

since $$x = \frac{n\,K\,l}{m}\,;\; y = \frac{D\,K\,n^2}{2\,m^2} \tag{6}$$

In seeking formulæ for the dimensions of the propeller, we may use either the indicated horse power, or the resistance of the vessel. If both are known, it is immaterial which is employed; but if the probable speed, and hence the resistance, is unknown, it becomes necessary to use the indicated horse power. The following formulæ for the diameter and pitch are given by Seaton.*

"The thrust of a propeller has been shown to vary directly as the area of the disc, that is, it varies as the square of the diameter; it has been also shown that the thrust varies as the square of the velocity of flow, that is, as the square of the product of revolutions and pitch. But the speed of the ship varies as the product of the revolutions and pitch, and the indicated horse power should vary as the product of thrust and speed."

Let D be the diameter, and P the pitch of the screw in feet, R the number of revolutions, and IHP the indicated horse power; then

$$\text{Thrust varies as } D^2 \times (R \times P)^2$$

$$\text{IHP varies as Thrust} \times (R \times P) \text{ or as } D^2 \times (R \times P)^3$$

Then $$\text{IHP} = K \times D^2 \times (R \times P)^3.$$

The value of K being substituted, the following formulæ are obtained:

$$\text{Diameter of screw} = 20{,}000 \sqrt{\frac{\text{IHP}}{(P \times R)^3}}$$

or

$$\text{Pitch of screw} = \frac{737}{R} \sqrt[3]{\frac{\text{IHP}}{D^2}}$$

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* Manual of Marine Engineering, p. 288.

For bluff cargo steamships substitute 17,000 for 20,000, and 660 for 737; while for torpedo boats and fast steam launches use 25,000 in place of 20,000.

PROPELLER WITH GUIDE BLADES.

This form of wheel, although but little used, is not without advantage. In the few cases in which it has been employed, the guide blades have been placed behind the wheel, where they serve to direct the currents into parallel lines, thus absorbing the energy which would otherwise have been lost by lateral slip. The loss of energy by slip is, then, a minimum with this type. Additional friction is introduced with the guide blades, but this is not so great as might be expected; for by the use of guides the diameter may be diminished. We have already seen that the part of the blade near the boss in the common propeller, does not and should not exert much of any thrust, on account of its inefficiency. In the guide blade propeller, on the other hand, this part of the blade has an efficiency nearly the same as that of every other part. This form of wheel may therefore project a *solid stream;* or, in other words, its diameter is a minimum for a given slip and thrust. Thorneycroft has obtained an efficiency of 66 per cent. with wheels of this type.*

The objections to the use of guide blades are three in number, viz.: the additional first cost, the liability to injury by floating obstacles, and the very low efficiency when going astern. Thorneycroft says:

"I consider that there are two kinds of vessels where the guide blade propeller might be used with advantage; they are sea-going vessels which often run in ballast, and, consequently, in their light trim, do not properly immerse a common propeller, and the other vessels for navigation where the draught of water is limited and necessitates the use of paddles or guide blades. In this case it would appear that the guide blade propeller may be more advantageously used than the paddle where high speed is required, owing to the reduction in the weight of the machinery, consequent upon the increased number of revolutions that may be used, at the same time retaining the light draught due to the paddle wheel, and having the further advantage of not increasing the extreme width of the vessel, which is an important feature in inland navigation."

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* Engineering, vol. xxxv, p. 461.

II.

Problem:—Given a vessel with a certain resistance; required the most efficient instrument of propulsion.

This is the problem of marine propulsion stated in its most general form; limited to the screw propeller, it becomes the subject of the following pages. That it remains unsolved is not due to lack of careful thought by talented men, for many able engineers have given it their best efforts. The uncertain nature of the conditions involved renders an exact solution impossible; and the variation of these conditions with the form and surface of the hull, reduces a general formula to a mere guess. But where theory has failed, experiment has in part succeeded, and it is quite probable that a large number of the propellers now in use, have an efficiency which approaches closely to the maximum.

The need of theoretical knowledge is still much felt however. The present propeller blade is, so far as shape is concerned, the result of much paring. It has come to have an increasing pitch, either axially or radially; frequently both. Sometimes the blade is inclined backward; again it is perpendicular to the shaft; the leading, or some other, corner is cut away; and it has many peculiarities such as the myriad inventor has seen fit to impose. But it has no definite mathematical relations with the work it has to do. Its efficiency cannot be analyzed so as to determine its various losses; and hence, time and effort are often wasted in the endeavor to diminish that which, it may be, is already so small as to be almost a minimum.

In the following discussion I have endeavored first to determine the shape of the blade by established principles, and then having given the resistance of the vessel and certain mathematical properties of the blade, to find the dimensions of the wheel. The judgment of the designer must, of course, always be relied upon; for there are too many variable quantities involved to admit of a mathematical maximum. I have chosen to trace the problem in its logical order, beginning with the resistance of the ship rather than with the indicated horse power, because of the more direct relation existing between the former quantity and the dimensions of the propeller. Since the resistance can in most cases be calculated when the indicated horse power is known, no difficulty exists should the latter quantity be given.

My method of treatment is then as follows:

1. Find the shape of a blade such that each particle of water shall

glide upon it without shock and be uniformly accelerated in the line of the shaft.

2. Find by experiment the relation between the acceleration and the intensity of pressure on the projected area of the wheel, this projected area to be upon a plane perpendicular to the axis. Then having assumed the slip and knowing the total resistance we can find the amount of this projected area and also, as will be seen, the diameter.

3. Find an expression for the efficiency; also expressions for the loss of energy by friction, by slip, and by edge-way resistance.

4. Analyze the loss by slip, separating it into its lateral and longitudidal components.

5. Find an expression for the loss of energy by the friction of guide blades. Then we may ascertain the efficiency of the guide blade propeller.

I will first consider the

PROPELLER WITHOUT GUIDE BLADES.

"The fundamental principle on which all propellers act, is that the reaction caused by projecting a mass of water in one direction produces motion of the ship in the opposite direction."*

It is clear then that our propeller is simply a sort of pump outside of the vessel, the sole duty of which is to give motion to the water. In order to avoid shock, this motion should be produced gradually. Further, it is clear that as the water passes across the blade, its velocity relative thereto remains constant; for the blade effects only the *direction* of the flow, and not its relative velocity. The following problem presents itself:—

Required the equation of the curve which a particle will describe, having a constant velocity in its path and a uniformly accelerated motion in the direction of X.

The following nomenclature will be observed. Units are foot, second and pound:

V_0 = velocity of water in direction parallel to axis at the leading edge of the blade; equal, if there be no following current, to the velocity of the ship.

V_1 = velocity of water in direction parallel to axis at the trailing edge.

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* Manual of Marine Engineering, Seaton, p. 272.

v_0 = whirling velocity of water relative to blade at leading edge; equal to the linear velocity in rotation of the corresponding point of the blade. Varies as radius and equals $2 \pi r n$.
r = variable radius of wheel.
r_1 and r_2 = radii of periphery and boss.
l_1 = breadth of blade.
S = area of surface of blade.
A = projected area of blades upon an athwart-ship plane.
p = intensity of pressure upon this area.
n = revolutions of wheel per second.
R = resistance of vessel in pounds.
f = acceleration in direction of axis.
$V_1 - V_0 = G$ = slip in direction of axis.
$\sqrt{V_0^2 + v_0^2}$ = resultant relative velocity of water.
= velocity of any point of blade.

Take the origin of coördinates at the leading edge, and let x be parallel to the shaft.

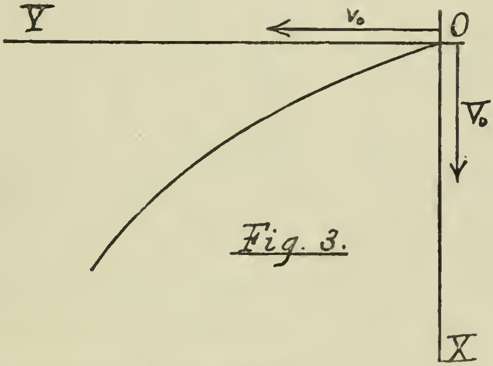

Fig. 3.

Then by the conditions of the problem

$$\frac{d\,x^2}{d\,t^2} = f \text{ and } \frac{d\,x^2}{d\,t^2} + \frac{d\,y^2}{d\,t^2} = \frac{d\,l^2}{d\,t^2} = V_0^2 + v_0^2$$

From the former we have by integration

$$\frac{dx}{d\,t} = f\,t + (C_1 = V_0)$$

and $$x = \tfrac{1}{2} f\,t^2 + V_0\,t + (C_2 = o)$$

whence $$t = \frac{1}{f}\,[\sqrt{V_0^2 + 2\,f\,x} - V_0]$$

And from the second condition we have

$$\frac{d\,l}{d\,t} = \sqrt{V_0^2 + v_0^2}$$

$$l = t\sqrt{V_0^2 + v_0^2} + (C_3 = o)$$

whence $$t = \frac{l}{\sqrt{V_0^2 + v_0^2}}$$

Equating the values of t gives

$$\frac{l}{\sqrt{V_0^2 + v_0^2}} = \frac{1}{f}\left[\sqrt{V_0^2 + 2fx} - V_0\right]$$

or $$l = \frac{\sqrt{V_0^2 + v_0^2}}{f}\left[\sqrt{V_0^2 + 2fx} - V_0\right] \qquad (1)$$

an expression for the length of the arc. Now to find the equation of the curve in terms of x and y, differentiate (1) and we have

$$d\,l = \frac{\sqrt{V_0^2 + v_0^2}}{\sqrt{2fx + V_0^2}}\,d\,x$$

But $$d\,l = \sqrt{d\,x^2 + d\,y^2}$$

$\therefore$ $$d\,x^2 + d\,y^2 = \frac{(V_0^2 + v_0^2)\,d\,x^2}{2\,f\,x + V_0^2}$$

and $$\frac{dy}{dx} = \sqrt{\frac{v_0^2 - 2\,f\,x}{2\,f\,x + V_0^2}}$$

This is the tangent of the angle which a tangent to the curve makes with the axis of X.

Multiplying by $d\,x$ we have

$$d\,y = d\,x\sqrt{\frac{v_0^2 - 2\,f\,x}{2\,f\,x + V_0^2}}$$

To integrate this let $\sqrt{\frac{v_0^2 - 2\,f\,x}{2\,f\,x + V_0^2}} = X.$

Then $$x = \frac{v_0^2 - V_0^2\,X^2}{2\,f(X^2 + 1)}$$

and $$d\,x = -\frac{v_0^2 + V_0^2}{f}\cdot\frac{X\,d\,X}{(X^2 + 1)^2}$$

$\therefore$ $$d\,y = -\frac{V_0^2 + v_0^2}{f}\cdot\frac{X^2\,d\,X}{(X^2 + 1)^2}$$

By formula of reduction (D) we have

$$\int X^2 (X^2+1)^{-2}\, d\,X = \tfrac{1}{2} X^3 (X^2+1)^{-1} - \tfrac{1}{2} \int X^2 (X^2+1)^{-1}\, d\,X$$
$$= \tfrac{1}{2} \left[\frac{X^3}{X^2+1} - X \tan.^{-1} X - K \right]$$

in which K is the constant of integration. We have then

$$y = -\frac{V_0^2 + v_0^2}{2f} \left[\frac{X^3}{X^2+1} - X + \tan.^{-1} X = K \right]$$

For $x = o, y = o$, and $X = \dfrac{v_0}{V_0}$: whence

$$K = \tan.^{-1} \frac{v_0}{V_0} - \frac{v_0\, V_0}{V_0^2 + v_0^2}$$

and this value substituted in the preceding equation will give us the equation required. A simpler form, and one more convenient for use, is the following:

$$y = (H + h)\,(K - \tan.^{-1} X) + X\,(H + x) \qquad (2)$$

in which $H = \dfrac{V_0^2}{2f}$; $h = \dfrac{v_0^2}{2f}$

$$K = \tan.^{-1} \frac{v_0}{V_0} - \frac{v_0\, V_0}{V_0^2 + v_0^2};\quad X = \sqrt{\frac{h - x}{x + H}}$$

and $f = \dfrac{V_1^2 - V_0^2}{2\,x_1}$, x_1 being the abscissa to the trailing edge.

This is the equation of a plane curve. To apply it to a propeller it must be wrapped upon a cylindrical surface and used as a directrix, just as the hypothenuse of a right-angled triangle, so wrapped, is used as the directrix of the *true screw*. The leading edge may have any shape.

AREA OF THE BLADE.

While f remains constant in equation (2), it may vary with the radius. The slip, G, may also vary with r, although constant in the equation of the curve.

We will take four cases.

A general approximate expression for the area will be

$$S = \int_{r_2}^{r_1} l_1\, d\, r$$

CASE 1.—*f and G constant.*

By equation (1) we find

$$l_1 = \frac{\sqrt{V_0^2 + v_0^2}}{f}\left[\sqrt{V_0^2 + 2\,f\,x_1} - V_0\right]$$

in which x_1 is the abscissa to the trailing edge for a breadth of blade, l_1.

But $$2\,f\,x_1 = V_1^2 - V_0^2$$

Hence $$l_1 = \frac{V_1 - V_0}{f}\sqrt{V_0^2 + v_0^2}$$

Substituting we have

$$S = \frac{V_1 - V_0}{f}\int_{r_2}^{r_1} d\,r\,\sqrt{V_0^2 + (2\,\pi\,n\,r)^2}$$

$$= \frac{2\,\pi\,n\,G}{f}\int_{r_2}^{r_1} d\,r\,\sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2}$$

Integrating

$$S = \frac{\pi\,n\,G}{f}\left[r\sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2} + \frac{V_0^2}{4\,\pi^2\,n^2}\text{ hyp. log. }\left(r + \sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2}\right)\right]_{r_2}^{r_1}$$

CASE 2.—$f = m\sqrt{V_0^2 + v_0^2}$; *G constant.*

These assumptions would probably be very suitable for a guide blade propeller. They give us

$$l_1 = \frac{G}{m} = \text{constant}$$

Hence $$S = \int_{r_2}^{r_1} l_1\,d\,r = l_1\,(r_1 - r_2)$$

CASE 3.—$f = m\sqrt{V_0^2 + v_0^2}$; $G = k\sqrt{V_0^2 + v_0^2}$.

By thus assuming the slip to vary from the boss to the periphery, we obtain an effect similar to that obtained by increasing the pitch radially in the common propeller.

In this case $$l_1 = \frac{k}{m}\sqrt{V_0^2 + v_0^2}$$

and

$$S = \frac{2\,\pi\,n\,k}{m}\int_{r_2}^{r_1} d\,r\,\sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2} = \frac{\pi\,n\,k}{m}\left[r\sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2} + \frac{V_0^2}{4\,\pi^2\,n^2}\text{ hyp. log. }\left(r + \sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2}\right)\right]_{r_2}^{r_1}$$

in which m and k are constants to be found, either from practice or by experiment.

In the case of very high speed vessels, as torpedo boats, or of large ships where practical considerations relative to the strength of the blade determine, in great measure, its proportions, it will probably be desirable to avoid the wide tipped blade to which the last set of assumptions will lead. Let us then assume f to vary as the square of the velocity and we will have

CASE 4.—$f = m\,(V_0^2 + v_0^2)$; $G = k\sqrt{V_0^2 + v_0^2}$.

$$\text{Then } l_1 = \frac{k}{m} = \text{constant},$$

$$\text{and } S = l_1\,(r_1 - r_2).$$

The conditions of this case are favorable to high efficiency, since the centre of effort is well out toward the periphery at an efficient part, and yet the tip of the blade is not so wide as to cause undue loss by friction.

DISCUSSION OF PROPERTIES OF BLADE.

If f and G are taken constant, then will the fore and aft length of the blade, x_1, be constant also; for we have

$$x_1 = \frac{V_1^2 - V_0^2}{2f}.$$

If $f = m\sqrt{V_0^2 + v_0^2}$ and G remains constant, then

$$x_1 = \frac{V_1^2 - V_0^2}{2\,m\sqrt{V_0^2 + (2\,\pi\,n\,r)^2}}.$$

If $f = m\sqrt{V_0^2 + v_0^2}$ and G also varies with r so as to equal $k\sqrt{V_0^2 + v_0^2}$, then

$$x_1 = \frac{k}{m}\left[\frac{k}{2}\sqrt{V_0^2 + (2\,\pi\,n\,r)^2} + V_0\right].$$

Lastly, if $f = m\,(V_0^2 \times v_0^2)$ and $G = k\sqrt{V_0^2 + v_0^2}$ then

$$x_1 = \frac{k^2}{2\,m} + \frac{V_0\,k}{m\sqrt{V_0^2 + (2\,\pi\,n\,r)^2}}.$$

In the side vertical projection of the blade we may draw either the leading or the trailing edge, and then by one of the above equations, find the other edge.

We will now consider the intensity of pressure upon the projected area.

Let $M =$ mass of water acted upon per unit of projected area; $p =$ pressure thereon. Then $p = Mf$.

M necessarily varies as $\sqrt{V_0^2 + v_0^2}$.

Then for f constant; $p \propto \sqrt{V_0^2 + v_0^2}$.

Then for $f = m\sqrt{V_0^2 + v_0^2}$; $p \propto (V_0^2 + v_0^2)$.

Then for $f = m(V_0^2 + v_0^2)$; $p \propto (V_0^2 + v_0^2)^{\frac{3}{2}}$.

We may find the radius, $\bar{r}$, to the point of mean intensity of pressure, thus:

$$\bar{r}\int p\,dr = \int p\,r\,dr.$$

For $p = p_1\sqrt{V_0^2 + v_0^2}$ this becomes

$$\bar{r} = \frac{p_1\int r\,dr\sqrt{V_0^2 + (2\pi n r)^2}}{p_1\int dr\sqrt{V_0^2 + (2\pi n r)^2}}$$

$$= \frac{\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}}}{12\pi^3 n^3\left\{r\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2} + \frac{V_0^2}{4\pi^2 n^2}\text{ hyp. log.}\left(r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right)\right\}}\left.\vphantom{\frac{A}{B}}\right\}_{r^2}^{r^1}$$

For $p = p_1(V_0^2 + v_0^2)$

$$\bar{r} = \frac{\int r\,dr\left(V_0^2 + (2\pi n r)^2\right)}{\int dr\left(V_0^2 + (2\pi n r)^2\right)}$$

$$= \left.\frac{\frac{1}{2}V_0^2 r + \pi^2 n^2 r^3}{V_0^2 + \frac{4}{3}\pi^2 n^2 r^2}\right]_{r^2}^{r^1}$$

For $p = p_1(V_0^2 + v_0^2)^{\frac{3}{2}}$

$$\bar{r} = \frac{\int r\,dr\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}}}{\int dr\left(V_0^2 + (2\pi n r)^2\right)^{\frac{5}{2}}}$$

$$=\left.\frac{\left(V_0^2+(2\pi n r)^2\right)^{\frac{5}{2}}}{\begin{array}{r}20\pi^2 n^2\Bigl\{\frac{r}{4}\left(V_0^2+(2\pi n r)^2\right)^{\frac{3}{2}}+\frac{3}{4}\pi n.V_0^2\Bigl(r\sqrt{\frac{V_0^2}{4\pi^2 n^2}+r^2} \\ \hline \frac{V_0^2}{4\pi^2 n^2}\text{ hyp. log. }\left(r+\sqrt{\frac{V_0^2}{4\pi^2 n^2}+r^2}\right)\Bigr)\Bigr\}\end{array}}\right]_{r^2}^{r^1}$$

This point of mean intensity is not to be confounded with the centre of effort. The position of the latter depends upon the distribution of the area, and it will lie beyond or within the point of mean intensity according as the projected width is greater beyond or within. I have not been able to find the radius to the centre of effort because I have no expression for the projected area, the terms involved becoming very unwieldy. This radius must therefore be found from the drawing by an approximate calculation. Calling it $\bar{r}$ we will have $\frac{\bar{r}}{r_1}=a=a$ constant which will differ for each rate of variation of f and G.

TO FIND THE DIAMETER.

Let $p'=$ the intensity of pressure, or thrust, upon the projected area at the centre of effort; then

$$p'\,A=R;\ \ A=\frac{R}{p'}.$$

In this expression R is the only known quantity. A is sought, hence we must find a value for for p'.

Let $f'=$ acceleration at the centre of effort; then

$$p'=Mf'$$

Now since M varies as $\sqrt{V_0^2+v_0^2}$, let it equal $\beta\sqrt{V_0^2+v_0^2}$; then

$$p'=f'\,\beta\sqrt{V_0^2+(2\pi n)^2(a\,r)_1)^2}$$

in which $(a\,r_1)$ is the radius to the centre of effort.

If $f=m\,(V_0^2+v_0^2)$ then

$$p'=m\,\beta\left(V_0^2+(2\pi n)^2(a\,r_1)^2\right)^{\frac{3}{2}}$$

To find p', therefore, we must first assume a value for r_1.

Using this value of p' we may find the value of A. If, now, we make the area of the athwart-ship projection in our drawing, equal to A, we can measure the radius; for the *width* of the blade is fixed by previous assumptions of f and G.

If this value of the radius found from the drawing, differs from that assumed in the formula for p_1, we must find another value for p', using a value of r_1 intermediate between the first assumption and the graphic value. This will give another value for A, and on the drawing, a more closely approximate value for r_1. Thus by trial we can arrive at the correct value for the radius. In the formula for p', the constant β is to be found by experiment, its value being

$$\beta = \frac{p'}{f' \sqrt{V_0^2 + (2\pi n)^2 (a r_1)^2}} \text{ in which}$$

p' is the experimental quantity.

If the projected area and the radius to the centre of effort were known in terms of r_1 we could find the exact value of r_1 by the equation $A = \frac{R}{p^1}$·

We may however construct such a formula, introducing a constant to be afterward determined. Take the fourth case, in which $f = m (V_0^2 + v_0^2)$ and $G = k \sqrt{V_0^2 + v_0^2}$. In this case we may assume A to be directly proportional to r_1 While this is not exactly true, it will be approximately so within modern limits in practice, and for extreme cases we may find other values for our constant. Further, A will be very nearly proportional to the breadth of the blade into the sine of the angle which its leading edge makes with the axis; that is, to l_1 sin. $\left(\tan.^{-1} \frac{v_0}{V_0}\right)$. Hence we may write

$$r_1 l_1 \sin. \left(\tan.^{-1} \frac{v_0}{V}\right) = \text{constant} \times \frac{R}{p'}$$

or since $l_1 = \frac{k}{m}$, and sin. $\left(\tan.^{-1} \frac{v}{V}\right) = \frac{v_0}{\sqrt{V_0^2 + v_0^2}}$

$$\frac{r_1 k v_0}{m \sqrt{V_0^2 + v_0^2}} = \text{constant} \times \frac{R}{m \beta (V_0^2 + v_0^2)^{\frac{3}{2}}}.$$

Taking v_0 at the radius to the center of effort which is $a r_1$, we have

$$2 \pi n a k r_1^2 = \text{constant} \times \frac{R}{\beta (V_0^2 + (2 \pi n a r_1)^2)}.$$

Letting φ represent the combined constants we have

$$r_1^2 = \varphi \frac{R}{n\,k\,(V_0^2 + (2\,\pi\,n\,a\,r_1)^2}$$

whence

$$r_1 = \sqrt{\frac{V_0^2}{(8\,\pi\,n\,a)^2}\left\{\sqrt{1 + \varphi\,\frac{16\,R\,n\,\pi^2\,a^2}{V_0^4\,k}} - 1\right\}} \qquad (3)$$

which is the formula required.

The constant φ will depend upon the number of blades, being twice as great for two blades as for four.

The value of φ is found by substituting experimental data in the formula,

$$\varphi = \frac{n\,k\,r_1^2\,(V_0^2 + (2\,\pi\,n\,a\,r_1)^2)}{R}$$

The method of laying down the blade is as follows: Fix the position of the leading edge. By means of the formula for x_1 find the side vertical projection of the trailing edge. By means of equation (2) find values for y_1 and lay down the athwart-ship projection of the trailing edge. In constructing the cross section of the blade at any radius use equation (2) giving f its value corresponding to the radius. It is to be observed that equation (2) is for a *plane* curve and the values of y must be measured on the arc and projected back.

Having the athwart-ship projection of both the leading and trailing edge we may take the radius r_1, such that the included area shall equal the required area, viz.: A. If r_1 has been already found by equation (3) the labor of measuring the area is avoided.

In the preceding discussion two constants occur which are to be found by experiment, viz.:

$$\beta = \frac{p'}{f'\,\sqrt{V_{o2} + (2\,\pi\,n\,a\,r_1)^2}}$$

and

$$\varphi = \frac{n\,k\,r_1^2\,(V_o^2 + (2\,\pi\,n\,a\,r_1)^2)}{R}$$

We may obtain roughly approximate values for these by reference to examples of the common screw in practice.

The values to be found are

$$p_1 = \frac{R}{A} \text{ and } f' = \frac{V_1^2 - V_o^2}{2\,x_1}$$

The following data is obtained from the Report of a Board of U. S. Naval Engineers.*

The propeller used was a Department screw of the following dimensions:

Diameter, 5 ft.; pitch, 7·5 ft. at the boss, and 8·625 ft. at the periphery; fraction of pitch, $6\frac{5}{32}$ inches; helicoidal area, 7·3 sq. ft. The projected area, as measured by myself from the scale drawing† in the Report, was 5·2 sq. ft.

The following table gives mean results of trials on April 1st, 2d, and 3d, 1880.

Average Revolutions per minute.	Distance run by screw in knots.	Slip of Screw in per cent. of its speed.	Speed of ship in knots per hour.	Gross IHP high pressure cylinder.	Gross IHP low pressure cylinder.	Total Gross IHP.	Horse-power required to give a speed of ten knots.
153·39	14·708	15.493	11·015	64·0826	37·1259	101·2084	70·76

The resistance of the vessel is not given in the report, but we may probably find it by the formula

$$R = \frac{0·6 \text{ IHP} \times 33000 \ddagger}{\text{pitch} \times \text{revs. per min.}}$$

By this we find $R = 1344·7$ lbs.

From the Table we have $V_0 = 18·57$ ft. per second, and $V_1 = 24·85$ ft. per second, $x_1 = 0·513$ and this is the same from root to tip.

Then we have $p' = \frac{R}{A} = \frac{1344.7}{5·2} = 257·6$ lbs. per sq. ft.

$$f' = \frac{V_1^2 - V_0^2}{2\,x_1} = \frac{617·5 - 344·85}{1·026} = 265·7 \text{ ft. per sec.}$$

$$\beta = \frac{p'}{f' \sqrt{V_0^2 + (2\,\pi\,n\,a\,r_1)^2}} = 0·0274$$

which involves the assumption that $a = \frac{3}{4}$.

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* Report of a Board of U. S. Naval Engineers of Experiments made on the Fish Commission Steamer "Lookout," November 24, 1880.

† See Plate II.

‡ This is based on Froude's experiments. See *Engineering*, vol. 21, p. 463.

Further, $G = k \sqrt{V_0^2 + (2 \pi n a r_1)^2} = 6{\cdot}28$

hence $k = \dfrac{6{\cdot}28}{\sqrt{V_0^2 + (2 \pi n a r_1)^2}} = 0{\cdot}18$

and $\varphi = \dfrac{n k r_1^2 [V_0^2 + (2 \pi n a r_1)^2]}{R} = 2{\cdot}7$

The value of φ will be effected by the diameter of the boss, but as the part of the blade near the root does very little work, it will scarcely be worth taking into account.

RECAPITULATION.

In designing a wheel, when R is given, the following quantities are either determined by other considerations or assumed:

Revolutions per second, n.
Slip in feet per second, $V_1 - V_0 = G$.
Acceleration in feet per second, f.

When f and G vary with the velocity, $\sqrt{V_0^2 + v_0^2}$, the quantities to be assumed are m and k.

The intensity of thrust at the centre of effort is found by the formula

$$p' = f' M = f' \beta \sqrt{V_0^2 + (2 \pi n a r_1)^2}$$

or for Case 4 when $f = m (V_0^2 + v_0^2)$

$$p' = m \beta [V_0^2 + (2 \pi n a r_1)^2]^{\frac{3}{2}}$$

in which a is the ratio between the radius to the centre of effort and the radius to the periphery.

The radius of the wheel is to be found graphically, the projected area and all other quantities involved being known. The projected area is found by the formula

$$A = \frac{R}{p'}$$

The radius of the wheel in Case 4 may be found, when φ is known, by the formula

$$r_1 = \sqrt{\frac{V_0^2}{8 (\pi n a)^2} \left\{ \sqrt{1 + \varphi \frac{16 R n \pi^2 a^2}{V_0^4 k}} - 1 \right\}}$$

All sections made by cylindrical surfaces having axes coinciding with that of the wheel, are curves which, when developed, are represented by equation (2) as follows:

$$y = (H + h)(K - \tan.^{-1} X) + X(H + x)$$

in which $$H = \frac{V_0^2}{2f};\ h = \frac{v_0^2}{2f};$$

$$K = \tan.^{-1} \frac{v_0}{V^0} - \frac{v_0 V_0}{V_0^2 + v_0^2};\ X = \sqrt{\frac{h - x}{x - H}}$$

We have also the relation

$$2 f x_1 = V_1^2 - V_0^2$$

in which x_1 is the abscissa to the point in the trailing edge.

In Case 4, $f = m(V_0^2 + v_0^2)$; $G = V_1 - V_0 = k \sqrt{V_0^2 + v_0^2}$; $H + h = \frac{1}{2m}$; and $l_1 = \frac{k}{m}$.

EFFICIENCY.

I have considered loss of energy to be due to friction, slip, and edge resistance. In discussing the loss by slip this term will be used to indicate the total actual yield of the water, and not simply its longitudinal component. Only one case will be discussed, viz., Case 4, in which $f = m(V_0^2 + v_0^2)$ and $G = k\sqrt{V_0^2 + v_0^2}$.

The resistance by friction varies directly as the surface and as the square of the velocity. Therefore if K represent the resistance of a unit of surface at a unit velocity, the resistance for an elementary band, $l_1\, dr$, will be

$$K l_1\, dr\, (V_0^2 + v_0^2)$$

and the loss of work per second will be thus multiplied by the velocity $\sqrt{V_0^2 + v_0^2}$, which will give us, for both face and back of blade,

$$2 K l_1\, dr\, (V_0^2 + v_0^2)^{\frac{3}{2}}$$

The integral of this between the limits r_1 and r_2 will give us the whole loss per second for one blade. Call this loss F. Then since l_1 is constant $F = 2 K l_1 \int_{r_2}^{r_1} \left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}} dr$

$$= 2 K l_1 \left[\frac{r}{4}\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}} + \frac{3}{8} V_0^2 \left(r \sqrt{V_0^2 + (2\pi n r)^2} + \frac{V_0^2}{2\pi n} \text{hyp. log.}\left\{r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right\}\right)\right]_{r_2}^{r_1}$$

The resistance by friction of such a surface as a smooth propeller blade is $1\frac{1}{4}$ pounds per square foot at ten knots per hour, and it varies as the square of the speed nearly.* Whence we find that the resistance per square foot at the velocity of one foot per second is

$$K = 0{\cdot}00438 \text{ lbs.}$$

The loss of energy by slip will be proportional to the square of the velocity impressed upon the water during its contact with the blade. Consider the blade stationary and the water in motion so as to preserve the same relative conditions.

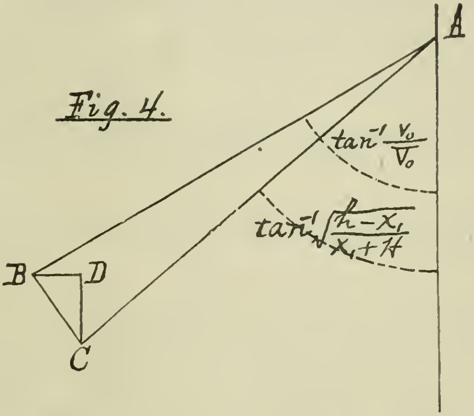
Fig. 4.
A
$\tan^{-1}\frac{v_0}{V_0}$
$\tan^{-1}\sqrt{\frac{h-x_1}{x_1+H}}$
B
D
C

Let *A B* represent the motion of the water, both in direction and velocity, at the leading edge; and let *A C* represent its motion at the trailing edge. *A B* and *A C* are equal, for the velocity of the water relative to the blade is not changed by contact therewith; the *direction* of motion only is changed. *B C*, then, represents the change produced in the motion of the water, both in velocity and direction.

How the energy lost by slip is that which is *stored* in the yielding fluid. The general expression for it is $\frac{1}{2} M V^2$; from which it appears that the amount of lost energy is proportional to the square of the velocity impressed, that is, to $\overline{B C}^2$.

The mass acted upon is proportional to $\sqrt{V_0 + v_0^2}$. We may then write for the loss of energy by slip per second for an elementary band,

$$C \sqrt{V_0^2 + v_0^2} \,.\, \overline{B C}^2 \, dr,$$

and for the whole blade, letting *L* represent the total loss,

$$L = C \int_{r_2}^{r_1} \overline{B C} \sqrt{V_0^2 + (2 \pi n r)^2} \,.\, dr.$$

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* Froude in Seaton's Manual of Marine Engineering, p. 288.

In this,

$$\overline{BC}^2 = \overline{AB}^2 + \overline{AC}^2 - 2\,\overline{AB}\,.\,\overline{AC}\,.\cos.\,BAC.$$

$$= 2\,(V_0^2 + v_0^2)\left\{1 - \cos.\left[\tan.^{-1}\frac{v_0}{V_0} - \tan^{-1}\sqrt{\frac{h - x_1}{x_1 + H}}\right]\right\}$$

$$= 2\,(V_0^2 + v_0^2) - 2\,V_0\sqrt{V_0^2 + 2fx_1} - 2\,v_0\sqrt{v_0^2 - 2fx_1}$$

$$= 2\,(V_0^2 + v_0^2) - 2\,V_0\,V_1 - 2\,v_0\sqrt{v_0^2 - V_1^2 + V_0^2}$$

Developing the last term by the Binomial Formula,

$$(v_0^2 - (V_1^2 - V_0^2))^{\frac{1}{2}} = v_0 - \frac{V_1^2 - V_0^2}{2\,v_0} - \frac{(V_1^2 - V_0^2)}{8\,v_0^3} - \frac{3(V_1^2\ V_0^2)^3}{48\,v_0^5}, \text{ etc.}$$

Taking the first three terms of this as sufficiently exact for our purpose, we have

$$2\,v_0\sqrt{v_0^2 - V_1^2 + V_0^2} = 2\,v_0^2 - V_1^2 + V_0^2 - \frac{(V_1^2 - V_0^2)^2}{4\,v_0^2}$$

whence

$$\overline{BC}^2 = 2\,V_0^2 + 2\,v_0^2 - 2\,V_0\,V_1 - 2\,v_0^2 + V_1^2 - V^2 + \frac{(V_1^2 - V_0^2)^2}{4\,v_0^2}$$

$$= (V_1 - V_0)^2 + \frac{(V_1^2 - V_0^2)^2}{4\,v_0^2} = G^2 + \frac{(V_1^2 - V_0^2)^2}{4\,v_0^2}. \qquad (4)$$

But $V_1 = G + V_0 = k\sqrt{V_0^2 + v_0^2} + V_0$

$$\therefore \quad \overline{BC}^2 = k^2\,(V_0^2 + v_0^2) + \frac{[k^2\,(V_0^2 + v_0^2) + 2\,k\,V_0\sqrt{V_0^2 + v_0^2}]^2}{4\,v_0^2}.$$

which, expanded, becomes

$$\overline{BC}^2 = k^2 v_0^2 + 2\,k^2\,V_0^2 + \frac{k^4\,V_0^4}{4\,v_0^2} + \frac{k^4\,V_0^2}{2} + \frac{k^4\,v_0^2}{4} + \frac{V_0\,k^3\,(V_0^2 + v_0^2)^{\frac{3}{2}}}{v_0^2} + \frac{k^2\,V_0^4}{v_0^2}.$$

Substituting this value of $\overline{BC}^2$ in our original equation, and arranging terms, we have

$$L = c\,k^2\int_{r_2}^{r_1} dr\,(V_0^2 + v_0^2)^{\frac{1}{2}}\left[v_0^2(1 + \tfrac{1}{4}k^2) + \frac{V_0^4}{v_0^2}(1 + \tfrac{1}{4}k^2) + \frac{V_0\,k\,(V_0^2 + v_0^2)^{\frac{3}{2}}}{v_0^2} + V_0^2(2 + \tfrac{1}{2}k^2)\right].$$

Integrating, we have for the loss of energy by slip per second for one blade,

$$L = c\,k^2 \left[\frac{1 + \frac{1}{4}k^2}{4} \left(r - \frac{V_0^2}{\pi^2 n^2 r} \right) \left(V_0^2 + (2\,\pi\,n\,r)^2 \right)^{\frac{3}{2}} + \right.$$

$$\tfrac{15}{8}\,r\,V_0^2\,(1 + \tfrac{1}{4}k^2) \left(V_0^2 + (2\,\pi\,n\,r)^2 \right)^{\frac{1}{2}} + \tfrac{15}{8}\,\frac{V_0^4 (1 + \frac{1}{4}k^2)}{2\,\pi\,n} \text{hyp. log.}$$

$$\left. \left(r + \sqrt{\frac{V_0^2}{4\,\pi^2\,n^2} + r^2} \right) + V_0\,k \left(2\,V_0\,r + \tfrac{4}{3}\,\pi^2\,n^2\,r^3 - \frac{V_0^4}{4\,\pi^2\,n^2\,r} \right) \right]_{r_2}^{r^1}$$

The edgeway resistance of the blade varies as the square of its velocity and as its thickness. If we assume the latter to vary inversely as the radius, and let T represent the total loss per second due to this cause, we may write at once

$$T = d \int_{r_2}^{r_1} \frac{(V_0^2 + v_0^2)^{\frac{3}{2}}\,dr}{r}$$

$$= d \left[\tfrac{1}{3} \left(V_0^2 + (2\,\pi\,n\,r)^2 \right)^{\frac{3}{2}} + V_0^2 \left\{ \sqrt{V_0^2 + (2\,\pi\,n\,r)^2} + \right. \right.$$

$$\left. \left. V_0 \text{ hyp. log. } \frac{\sqrt{V_0^2 + (2\,\pi\,n\,r)^2} - V_0}{2\,\pi\,n\,r} \right\} \right]_{r_2}^{r_1}$$

I have no data at hand by which to determine the value of the constants c and d.

Calling the efficiency E, and the energy transmitted to the wheel per second, W, we have

$$E = \frac{W - \Sigma \text{ losses}}{W}$$

$$= 1 - \frac{N}{W}[F + L + T] \qquad (5)$$

N being the number of blades.

These expressions for the losses apply only to the case assumed, viz.: that in which

$$f = m\,(V_0^2 + v_0^2) \text{ and } G = k\sqrt{V_0^2 + v_0^2}$$

In a propeller wheel, that part of the blade which is nearer the hub is inefficient on account of lateral slip, while that part which is near the periphery is inefficient on account of friction, I have therefore assumed G, the longitudinal slip, to diminish from the periphery to the hub, in order to lessen the amount of work done at an inefficient part of the blade; and have taken f as increasing from hub to periphery in order to avoid too great a width at the latter. The edges should be sharpened from both face and back, and it would be advisable to round the corners as is done in ordinary practice.

I will now consider briefly, the

PROPELLER WITH GUIDE BLADES.

The primary object of guide blades is to prevent loss by lateral slip. They give an additional advantage, however, by increasing the efficiency of the central part of the wheel, so that for a given thrust, a smaller diameter may be used than with the common wheel.

The guide blades should be placed behind the propeller. It would, perhaps, be better to place them in front of the wheel, if we considered only the action while going ahead; but when going astern this arrangement would be very ineffective.

In applying the method of the previous discussion we have but to take G constant and $f = m \sqrt{V_0^2 + v_0^2}$. The guide blade should be constructed in the same way as the propeller blade, using for V_0 the lateral slip, found thus:

By equation (4) we have

$$\overline{B\,C}^2 . = G^2 + \frac{(V_1^2 - V_0^2)^2}{4\,v_0^2}$$

This last term must represent the lateral slip $B\,D$, figure 4; hence,

$$B\,D = \frac{V_1^2 - V_0^2}{2\,v_0}$$

In case the guide blades are placed before the wheel, the initial whirling velocity, v_0, of the water relative to the wheel, would no longer be the velocity of the latter, but would be this velocity plus the velocity imparted by the guide blade. That is

$$v_0 = 2\,\pi\,n\,r + B\,D = 2\,\pi\,n\,r + \frac{V_1^2 - V_0^2}{2\,v_0}$$

whence

$$V_0 = \pi\,n\,r + \sqrt{\pi^2\,n^2\,r^2 + \tfrac{1}{2}\,(V_1^2 - V_0^2)}$$

A comparison between the efficiencies of the guide blade propeller and the common wheel reduces itself to a comparison between the lateral slip of the common wheel and the excess of friction of the guide blade wheel over the common one. The frictional loss is found in both cases by the formula for F, which applies to any blade of constant width. If the guide blade wheel is enclosed in a cylinder, the friction of this also is to be taken into account.

For the lateral slip we have:

Loss of energy per second by lateral slip for one blade

$$D = C \int_{r_2}^{r_1} \overline{D\,B}^2 \sqrt{V_0^2 + V_o^2}.\, dr$$

$$= \frac{C}{4} \int_{r_2}^{r_1} \frac{(V_1^2 - v_0^2)^2}{V_o^2} \sqrt{V_o^2 + v_o^2}.\, dr$$

$$D = \frac{c\,k^2}{4} \Big[\tfrac{1}{4} \left(k^2 r - \frac{V_o^2 (k^2 + 4)}{\pi^2 n^2 r} \right) \left(V_o^2 + (2\,\pi\,n\,r)^2 \right)^{\frac{3}{2}} +$$

$$V_o^2 r\,(2\,k^2 + 6) \left(V_o^2 + (2\;V n\,r)^2 \right)^{\frac{1}{2}} + \left(\frac{15}{8}\,k^2 + 6 \right) \text{hyp. log.}\,(r +$$

$$\sqrt{\frac{V_0^2}{4\,\pi^2 n^2} + r^2} \bigg) + 4\;k\;V_o \left(2\;V_0^2 r + \tfrac{4}{3}\,\pi^2 n^2 r^3 - \frac{V_0^4}{4\,\pi^2 n^2 r} \right) \Big]_{r_2}^{r_1}$$

which applies to a wheel having the conditions of case 4. This expression involves also the loss by centrifugal action, which in the guide blade wheel can be counteracted by a proper adjustment of the guides.

If F_1 and F_2 represent the fractional losses of the common and and guide-blade wheel respectively, then a comparison between D and $(F_2 - F_1)$ will determine the relative efficiency.

Fig. 5

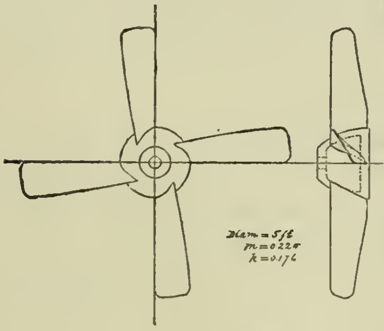


Fig. 6.

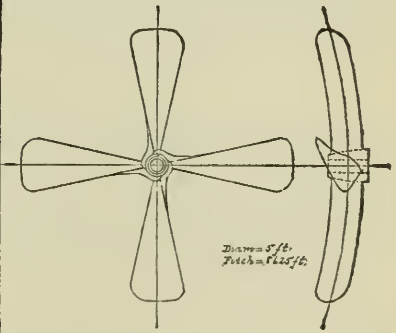


Fig. 5 shows a wheel designed by the method of Part II with the conditions of Case 4. It is calculated to exert the same thrust as the wheel shown in Fig. 6, which is a U. S. Navy Department wheel.

Hoboken, N. J., June, 1883.

NOTE ON CENTRIFUGAL FORCE IN TURBINES.

By R. H. Thurston.

[American Association for Advancement of Science, August, 1883.]

A note by Mr. J. P. Frizell (Journal of the Franklin Institute for June) especially interests the writer, as he has, recently, also noted the same defect in the accepted theory. It is so obvious as to require no proof that centrifugal force, even where it is necessarily considered at all, depends for its measure upon the actual rotation of the mass of fluid, and not at all upon the movement of the wheel, except so far as the latter controls the former. In water-wheels, the two rotations are very different in their angular measures.

Plotting the path of the water in space, it will often be found that the line is so nearly rectilinear that the action of this force may be neglected as unimportant in practice. This is probably the case, for example, in the Vallet wheels. In the Whitelaw turbine, or "Scotch reaction wheel," as it is sometimes called, the spiral form given the arms may often be given such proportions that the path of the water may be nearly a straight line to the exit, and centrifugal force thus rendered so small that it may be neglected in the theory of that wheel. The writer has been interested in noting how much this method of treatment simplifies the theory of turbines, and how much more nearly, in some cases, the results accord with experiment. In the last form of wheel, for example, the expression for maximum efficiency becomes

$$E = \frac{1}{sec^2\,\theta},$$

and the speed of maximum efficiency becomes such that the orifice moves with the velocity due the head. The maximum effort is exerted, as it should be, when the wheel is held fast, and the effort becomes zero, when the speed of orifice becomes twice that velocity.

For the common case, in which the velocity of rotation of the water is a maximum at its entrance into the wheel from the guides, and becomes zero at exit from the wheel, varying in the interval by a uniform retardation, we have, when v_1 is the entering "*whirl*," r_1 and r_2 are the two radii of the wheel, and $r_2 = n\,r_1$;

$$v = \frac{r_2 - r}{r_2 - r_1}\,v_1 = \frac{n - \dfrac{r}{r_2}}{n - 1}\,v_1;$$

the work done by or against centrifugal force is

$$W = \frac{D\,Q}{g} \int_{r_1}^{n\,r_1} \frac{v^2}{r}\,d\,r\,;$$

$$= \frac{D\,Q}{g} \cdot \frac{v_1^{\,2}}{(n-1)^2} \int_{r_1}^{n\,r_1} \left(n - \frac{r}{r_2}\right)^2 \frac{d\,r}{r}\,;$$

$$= D\ Q\,\frac{v_1^{\,2}}{2\,g} \cdot \frac{2\,n^2 \log_e n - 4\,n\,(n-1) + n^2 - 1}{(n-1)^2}$$

Applying this to the outward flow wheel of the Fourneyron type, having uniform radial flow, it is found that the effort due centrifugal force is about one-quarter the head due the velocity of entering whirl; but this velocity is that due to about one-third the total head, in this particular example, and it follows that the accelerated flow is not far from one-half that predicted by the usual theory, and is not very far from what Mr. Frizell gives as the results of Mr. Francis' experiments, and if the energy is given a uniform decrement, *i. e.*, $dv^2 =$ constant and $dv \propto \frac{1}{2\,v}$, for which case, $f(n) = \frac{2n \log_e n - 2(n-1}{n-1}$, the corres-correspondence is almost exact, a coincidence, possibly, however, as the writer has not investigated that particular case.

It thus becomes evident that, in the general equation of efficiency for wheels of uniform radial flow, for which the writer gets the expression below, the functions representing this force may take the place in the formula there given them, and that the theory of the turbine, thus modified, is a much more manageable one in application than that previously held.

The general equation is, as derived by the writer,

$$E = \frac{(n^2+1)\,(2\,a\,r_1\,v_1 - a^2\,r_1^{\,2}) - f(n)\,v_1^{\,2}}{n^2\,v^2 \sec^2\theta + 2\,a\,r_1\,v_1 - a^2\,r_1^{\,2} - f(n)\,v_1^{\,2} + f(f)\,v_1^{\,2}}$$

when the angular velocity is denoted by a and the coefficients for centrifugal force and for friction are taken constant, as they may be for any one class of wheel, as $f(n)$ and $f(f)$, the delivery angle of the wheel being θ.

At the best speed, $v_1 = a\,r_1$; and

$$E = \frac{(n^2 + 1) - f(n)}{n^2 \sec^2\theta + 1 - f(n) + f(f)}\,;$$

which becomes unity when $f(f) = 0$ and $\theta = 1$. It is seen that the value $f(n)$ appearing in both numerator and denominator affects efficiency but little, since the expression is, for good wheels, nearly unity.

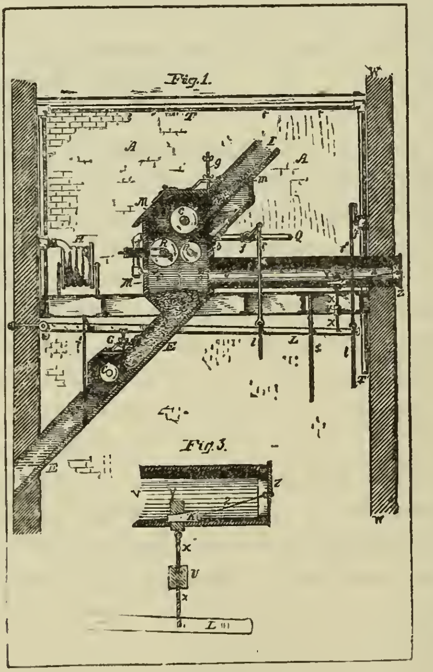
Hoboken, July 31, 1883.

PREVENTION OF DUST EXPLOSIONS AND FIRES IN MALT MILLS.

By C. JOHN HEXAMER.

[Read at the Stated Meeting of the Franklin Institute, June 20, 1883.]

In consequence of the lateness of the hour at which I spoke, and not having satisfactory drawings prepared at the time, I did not explain my automatic devices (for closing communicating openings between the mill house and the brewery, and for turning on live steam and a supply of water automatically by an explosion or fire) in my paper on "Dust Explosions in Breweries," read before the Institute, January 17th, 1883, and published in the JOURNAL for February.



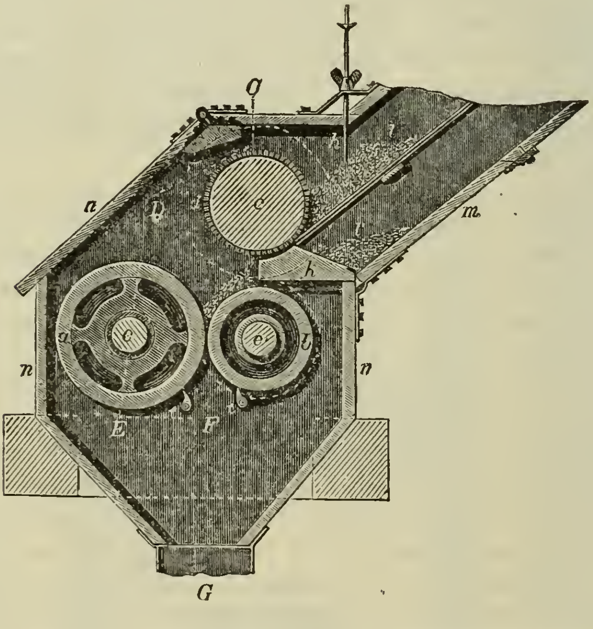
Without taking your valuable time for a recapitulation of what I then said concerning the hazards of malt mills, I will ask your kind attention to Fig. 1, which represents a vertical section of the mill room; the heavily shaded sections on the extreme right and left represent the walls of the mill building; *I* the influx pipe of the grain as it comes from the cleaners; *M* the mill box, containing a feeding device *g* and *c*; *R R* the crushing rolls; *f* a live steam supply pipe with openings *o, o, o, o,* into the mill box; *E* the exit or grain discharge pipe; *G, C* the discharging apparatus, above which is shown a plenum of ground malt; *J* a gate attached to the lever *L* by the rod *r′*; *V* a large vent pipe, extending from the mill box through the wall to the outside of the building, closed by the capping *Z;* *T* a water pipe with sprinkler openings *t, t*; *H* a hose attached to the water pipe.

Having pointed out the principle parts of the mechanism, I will now describe its method of working, and will begin with the grain as it leaves the cleaners and enters the mill box, until it leaves the mill room and enters the elevator, which is situated outside of the mill room beyond the wall to the left and discharge pipe *E*, which communicates with it.

The grain from the cleaners enters the influx pipe *I*, and rolling down the pipe it passes over sieve-like perforations in the pipe, causing dust and foreign particles smaller than the malt grains to drop through the small openings in the pipe into an inclosed dust chamber *m*. The grain then passes over a powerful magnet, not shown in the figure (which, however, is not a part of my invention), cleaning it of the iron and steel particles it may contain. It now enters the feeding apparatus *c, g*. The grain is then fed into the *gearing* rolls *R, R*, held together by powerful springs shown on the outside (left side) of the mill box; the reasons for using these I fully explained in my last paper. The crushed grain accumulates in the receiving hopper and is discharged by the discharger *C, G*. As many present may not have heard my explanation at the January meeting, I will briefly repeat the reasons for the introduction of the feeding and discharging device which otherwise might to many seem but an unnecessary complication.

The great danger in malt mills is that, in case of an explosion, the explosive force and fire are not confined to the mill only, but run from the mill into the elevator, and from there are distributed to the adjoining brewery buildings. To check the force and fire of an explosion we must put a barrier between the mill box and the elevator. This can best be accomplished by placing a receiving hopper below the rolls, kept well filled while the mill is in operation, and from this hopper feed into the elevator cups. We thereby have a barrier of meal between the elevator and the mill, a barrier almost as effective as one of sand. But the important point in this case will be to keep the hopper well filled, for a hopper which is not full merely acts as a conduit and not as a barrier to an explosion. In order that the attendant of a mill shall not be relied upon, the receiving hopper should be kept filled automatically. For this purpose I suggested the following device, shown in the accompanying cut (Fig. 2); a device which was not a new invention, but an adaptation of something well known, for a new purpose. A "feeder" for grain mills used for a long time in Germany is

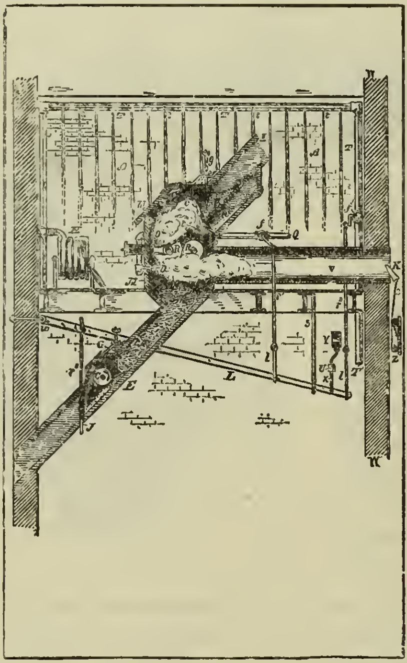
Fig. 2.



shown in the cut, *e* and e^1 being the rolls of the mill, *n*, *n*, being the mill box, while *G* is the spout ordinarily leading into the elevator boot; in mills properly constructed, into a receiving hopper; *c* is a roll of wood usually covered with a covering, and teeth *d* of steel projecting from 2 to 3 millimeters, we propose to use a covering and teeth of copper, phosphor bronze, or some other metal which will strike no sparks; *l* is an inclined plane of metal with sieve-like perforations large enough to allow dust to drop through them; *h* is a gauge which regulates the flow of grain on to the feeding roll *c*; l^1 is a "dust chamber," which may be made of any size, and which may be cleaned out through the door *m*; *k* is the receiving block of wood covered with copper, and at a distance of 1·9 millimeters from the teeth of the feeding roll. The operation of this feeder, which is a Belgian invention, and which has been used with great success in Germany, is very simple. The grain after passing through a cleaner drops on to the incline, is there separated from any remaining dust; and is then allowed to run in a thin stream—regulated by the gauge—on to the receiving block, where it is fed into the mill by the revolution of the feeding roll. We propose to utilize this invention, modified as above, to keep our receiving hopper at all times full. The crushed grain instead of falling directly into the elevator cups on leaving *G*, will fall into a receiving hopper, from which a pipe or incline (without perforations) leads the meal past a gauge, on to a feeder as described above, from which it passes in a thin stream into the elevator. On setting up a mill the relative points for both gauges will be determined, the grain-feeder and the mill will be set in motion while the *discharger* will remain at rest until the receiving hopper is filled, when it will also be set in motion; this operation will be performed by the erecting machinist; for after the first grinding the receiving hopper will always be full, as the grain will be fed in just as rapidly at the top as the meal is discharged at the bottom. The only case in which the receiving hopper could become empty is one, which would very rarely occur in a well-conducted brewery; that is when the mill is running while no grain is on the incline. When this does occur, the above-described process must be repeated.

Having explained the ordinary working of the mill, which is contained in a strongly-built brick building, with a brick arched floor and ceiling, the discharge pipe, which passes through the brick and iron floor, being made of thick and strong iron, so as to withstand great shocks, let us consider the operation of the device under extraordinary circumstances. Let us suppose that, either by the striking of a spark or frictional heat, an explosion is caused in the mill box (explosions and fires almost invariably originate in the mill box at the rolls). The tendency of all explosions or pent-up forces is to seek the easiest means of exit, and would in this case, in all probability, pass out through the large-sized vent pipe *V* (Fig. 1), knocking out the capping, *Z*. Fig. 3 shows an enlarged section of the vent pipe and arrangement of the capping. The cap *Z* consists of a hood similar, only larger in size, to the caps used in summer to close up stovepipe holes. To this cap is attached a rod *Q*, which connects the caps with a key x, fitting into the slotted support y, which passes through an opening in the bottom of the ventpipe. The key and its slotted holder will be made either of a certain variety of vulcanized rubber, with which I am at present experimenting, or of boxwood soaked for a time in oil. The cap being knocked off, the rod Q would dislodge the key x; the support y would pass through the slit in the vent pipe, and the lever L, supported by the rope Xx, would be released and drop. The lever, which is weighted at the point of contact with the rope x, has its fulcrum at w (Fig. 1), where it is attached to the wall. In falling, the lever carries with it the rod r'', which is connected as shown in Fig. 1 with the cock f' of the water supply pipe T, and by falling turns on the water, which rushes into the sprinklers t, t and hose H. The lever L also carries with it the rod r', connected with the cock f of the life steam supply pipe, turning on the steam, which rushes into the mill box through the numerous openings o, o, o. At the same time a strong rod r', attached to an iron gate J, is forced down, cutting off all communication between the mill room and the elevator in the adjacent brewery. This gate, on falling, will meet

Fig. 4.



with no serious obstacles from crushed grain in the pipe at this point, as the grain is only discharged in a thin, regular stream by the discharger *G C.*

The result of all this is shown in Fig. 4. The steam is rushing into the mill box; the water is turned on; the hose and sprinklers are in operation; the gate is shut, etc.

An explosion would not likely find an exit in the supply pipe *I*, as this is securely closed by the wheel *c*, the strong gauge, *h* and a plenum of malt *l* (Fig. 4), while the effect of an explosion on the exit pipe *E* (Fig. 1) would be to pack the crushed malt more tightly, forming a more impenetrable barrier than before, as is the case in the well-known experiment of "a funnel filled with sand."

But let us suppose that the mechanism does not work as we anticipated. Let us suppose that the capping is rusted fast; that the key sticks, or, as has just been suggested by one of the members, that the explosion does not follow out the easy path I have made for it, but knocks the strongly-built mill box to pieces, what will occur? In this case the fire will not be as readily smothered as would have been the case under the first supposition, when it would have been "nipped in the bud." But the heat in the mill room would soon rise to a considerable temperature, and on reaching 150° Fahrenheit, would melt the fusible solder catches which join the different sections of the rope,* *x, x* (Fig. 3), *v* being one of them greatly exaggerated; the lever *L* would fall, and the mechanism would work as well as in the first case described. Let us make the very improbable supposition that the fusible catches, by some unforseen accident, will not operate. In that case the flames, which spread very rapidly throughout the finely-divided dust in the room, would soon reach the portion of the rope *x, x*, above the floor. This, which is prepared especially inflammable, would rapidly burn through, and the mechanism operate as before.

So that the building may not be flooded and filled with steam after the fire is extinguished, there are cocks (not shown on the figure) on the supply pipes, placed below the automatic cocks, by which the water and steam may be turned off until the apparatus is repaired. That no ignorant or malevolent employé may turn these off, and thus throw out the supply of the automatic system, the lower cocks are so arranged that they cannot be turned unless the lever *L* has fallen.

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* The rope consists of small, extremely inflammable prepared sections, held together by fusible catches.

Instead of steam, a supply of carbonic acid gas might be turned on automatically in the same manner; but as it would be more costly and troublesome to keep a supply of this on hand, it is preferable to use steam, especially as there must always be a supply of steam in the boiler, while there is danger of an explosion or fire—that is, while the mill is running.

In reply to a question of one of the members, I will also state that the iron gate *J* has only been introduced as another factor of safety, for as long as the mill is properly operated—that is, as long as the receiving hopper is kept full, the crushed grain will form a perfect barrier to all explosions. It is only where the mill has been carelessly allowed to run without feeding and grinding, and the hopper has thus become empty, and not being refilled at the next grinding, an occurring fire would, by the automatically closing gate, be prevented from entering the adjoining brewery building through the exit pipe E (Fig. 1).

THE GREEN MOUNTAIN RAILWAY.*

The leading attraction which Maine has to offer her summer visitor the present season is her mountain railway—from the shore of Eagle Lake to the summit of Green Mountain, on the Island of Mount Desert.

Several weeks since, we promised our readers a more detailed description of this railway and its leading features of construction than had been given to the public, as the fact of its being the second cog railway in this country and the third ever in existence has made the work one of more than ordinary interest.

The survey for the Green Mountain Railway was made in December and January, 1882–3, by Mr. Alden F. Hilton, formerly Engineer of the European & North American Railway. The mountain at the time was covered with snow and ice, and during the entire progress of the survey the mercury indicated nothing above a zero temperature, and was some of the time eight degrees below. The point first selected turned out to be the very best location on the whole mountain and was followed in the construction of the line, as was also the whole general plan proposed by Mr. Hilton. He was called away, however, on the

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* Abstracted from the *Mining and Industrial Journal*, Bangor.

Megantic survey, and Mr. Warren Nickerson, of Orrington, was employed as constructing engineer, under whose supervision the entire work of construction was performed.

THE ROADWAY.

The roadway for the most part, and over all heavy grades, is constructed upon the solid ledge. Where the stringers (longitudinal timbers) rest directly on the ledge, an iron bolt (1¼ inch iron) is driven through the timbers and into the ledge at intervals of six feet. Where, in order to make regular grades, the stringers are raised above the surface, bed ties are used every six feet, and back of every bed tie, on all ledges, two and three 1¼ inch iron bolts are firmly set into the ledge. Not only this, but all longitudinal timbers upon the bed ties are bolted to them with the 1¼ inch bolts, and every stick resting upon the ledge is carefully fitted to its inequalities, some sixty first-class ship-carpenters and axemen having been employed upon the work expressly for this purpose, at prices ranging from fifty to seventy-five per cent. above the cost of labor in ordinary railroad construction. The stringers were all laid true to grade, and the "centres" given from the instruments on every bed tie.

The track ties (sleepers) are laid directly upon the stringers, exactly two feet apart (from centre to centre), and back of each tie (which is six inches square by six feet long) two ⅞ inch iron bolts are driven into the stringers, each tie being grooved or "gouged" so that the bolts fit firmly into them, thus preventing lateral as well as longitudinal movement.

THE TRACK.

Upon these ties the "T" (or ordinary track) rails are laid to a gauge of 4 feet 7½ inches, or one inch narrower than the standard gauge railways of the country. These rails are coupled together the entire length of the road by the ordinary "fish plates" and track bolts (four bolts to each rail), and fastened to the sleepers by common railroad spikes, two upon each end of every sleeper. Every T rail has also four "slots" into which the spikes are firmly fitted. The cog rail is made from two plates of angle iron which form the base as well as the upright stand into which the cogs are fitted. The "cogs" are made from 1¼ inch iron, especially selected for the purpose, and all made in one set of rolls in order to insure uniformity in size.. Each bolt is equal to a *direct* strain of about thirty tons, while the maximum load will never exceed sixteen tons. These cog rails are secured to the ties by fourteen lag screws ($5\frac{1}{2}$ inches long) in each 12-foot section of the rail, or two lag screws every two feet, this of course being doubled at each joint.

For the purpose intended, the road is without doubt equal to five times the strain to which it will ever be subjected, and, considering the difficulties under which it was built, is certainly a marvel of railway engineering and construction.

THE ROLLING STOCK.

The engine was built by the Manchester Locomotive Works, with all the improvements suggested by thirteen years' successful operation of the White Mountain road. The ascent is made by steam power; the descent with compressed air—or perhaps it is more correct to say through allowing the air to escape from the cylinders. The engine is always set in the "forward gear"—or as if going ahead—even in coming down the mountain, and is never reversed when backing up as is the case with an ordinary locomotive. As an illustration, let us suppose a "dead" engine—or an ordinary locomotive with no steam—standing on a level track and set in the forward gear. Attach an engine under steam and haul the dead locomotive backwards a considerable distance. Release it, and the compressed air worked into the cylinders and boiler will send it forward to the starting point. The action is precisely the same with the mountain engine, and it absolutely cannot come down the mountain excepting as the air is allowed to escape.

The entire mechanism of the engine is double—four cylinders, two cog wheels and two driving shafts. The power is not carried direct from the cylinders to the cog wheel axle, but to shafts upon which there is a small gear wheel which works into one $5\frac{1}{2}$ times its size upon the cog wheel axle. Upon the cog wheel axles there are two ratchet wheels into which two pawls are constantly dropping, and in the event of the breaking of any part of the engine, either one of these wheels, with its pawl, will hold the entire train on any of the grades. In addition to these provisions for safety, there are two "band" brakes on the smaller shafts which may be instantly applied by the engineer.

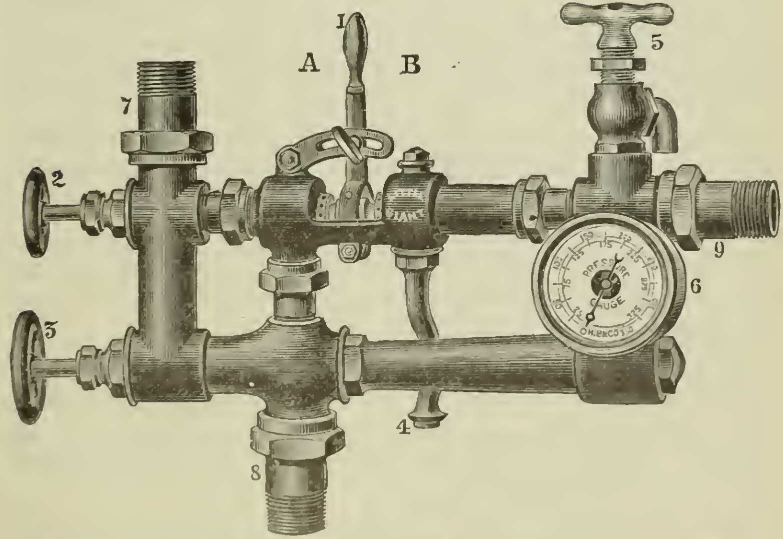
The passenger and construction cars were built by the Hinckley &

Egery Iron Company, of this city, the former being transported in sections to the foot of the railway and there set up. The floor and seats are adjusted to the average grade, and the sides are open to admit of unobstructed observation, and the construction is first class in every respect. The car is never attached to the engine, but is pushed ahead. It is provided with double hand-brakes, two cog wheels, and a rachet wheel with a pawl, which would instantaneously stop and hold the car on any of the steepest grades, if it were ever possible for the engine to get away.

IMPROVEMENTS IN APPARATUS FOR TESTING BOILERS.

[From the Report of the Secretary, May 16, 1883.]

The accompanying illustration represents the "Little Giant" Boiler Testing Apparatus, made by the Rue Manufacturing Company of Philadelphia.



Respecting the usual cold water test applied for this purpose, it is alleged that the shock of forcing water into a boiler under pressure by means of a pump is equivalent in its effects to a series of blows against the boiler shell; and that these blows are liable to, and in many instances do, result in producing serious injury to the boiler, the extent of which in the majority of instances may never be known save indirectly. If strained by this operation in some of its parts, to nearly the point of rupture, it is reasonably alleged that it may give way at some future time under a much less pressure than that at which it was tested.

From these considerations, therefore, it is affirmed that the safest method of making such tests and that which has received the sanction of experienced engineers, has hitherto been to fill the boiler full of cold water, then apply a slow fire and obtain the desired pressure by the expansion of the water.

The method which involves the application of the apparatus herewith illustrated, consists in filling the boiler full of hot water (of say 180°F. or more), then applying the required pressure by means of an injector constructed for the purpose, which also continues to add heated water to the boiler. A safety- or relief-valve is set to open at the pressure at which it is desired to test the boiler, and the operation of the injector is such as to accumulate and maintain that pressure constantly and as long as may be required. By this means, it is affirmed, that whatever the pressure at which the boiler is to be tested, that pressure will be perfectly uniform throughout, and in its effects on the shell substantially similar in all respects except in degree to the pressure that obtains when the boiler is in use under steam. Another important advantage of this apparatus is claimed to be the accumulation and constant maintenance of whatever pressure may be desired, uninfluenced by slight leaks.

For locomotive and boiler work the apparatus is claimed to possess many features of advantage over the usual pump, of which the speed with which it operates, is not the least.

The apparatus consists in the arrangement of an injector and ejector especially constructed and connected for the purpose above described.

The accompanying engraving represents the appearance of the apparatus. As seen, it consists of two instruments, the one filling the boiler, the other applying the pressure.

The makers explain that their apparatus will fill the boiler to be tested at the rate of 2,000 gallons per hour with hot water. The portion of the apparatus applying the pressure has a capacity of 400 gallons per hour, and will accumulate from three to five times the initial pressure according to circumstances. It is further explained that it can be used with any pressure of steam from 10 pounds to 150 pounds.

Briefly, then, the instrument herewith shown is an apparatus to test boilers with warm water under a continuous even pressure without shock or jar, which cannot be done with a pump and cold water; it will produce and maintain any desired pressure up to three times the steam pressure used, and can be made to five times when required.

The details of the apparatus will be understood from the following references to the engraving:

No. 1. Adjusting Lever, Instrument, No. 1.
No. 2. Steam Valve, Instrument, No. 1.
No. 3. Steam Valve, Instrument, No. 2.
No. 4. Overflow from Instrument, No 1.
No. 5. Safety Valve.
No. 6. Pressure Gauge.
No. 7. Steam Connection.
No. 8. Water Connection.
No. 9. Boiler Connection.

MINERAL PRODUCTS OF THE UNITED STATES.

A report entitled "The Mineral Resources of the United States" is now in the press, and will shortly be published, by Mr. Albert Williams, Jr., chief of the division of Mining Statistics and Technology, United States Geological Survey, Hon. J. W. Powell. Director. This report is for the calendar year 1882 and the first six months of 1883. It contains detailed statistics for these periods and also for preceding years, together with much technical and descriptive matter. The compilation of special statistics has been placed by Mr. Williams in the charge of leading authorities in the several branches, and the results will therefore be accepted with confidence. The following totals of the production of the more important mineral substance are from advanced proofs:

Coal.—The only statistics in which the trade is interested are those relating to the amount of coal which is mined for and reaches the market. There is besides a local and colliery consumption which is usually disregarded in statistics, and which ranges from 5 to 6½ per cent. on the total shipments. Of what may be called the commercial product, the quantities in 1882 were: Pennsylvania anthracite, 29,120,096 gross tons; bituminous, brown coal, lignite, and small lots of anthracite mined outside of Pennsylvania, 57,963,038 gross tons; total, 87,083,134 gross tons. The spot value of the commercial product was as follows: anthracite, $65,520,216; bituminous and other coals, $72,453,797; total, $137,974,013. During the first six months of 1883 the output was: Pennsylvania anthracite, 14,010,767 gross tons; bituminous and all other coals, 30,000,000 gross tons; total, 44,010,767 gross tons. The spot value of the commercial product during the first half of 1883 was: Pennsylvania anthracite, $31,524,226; bituminous and other coals, $37,500,000; total, $69,024,226. Including the local consumption, etc., the total product in 1882 may be stated at 92,219,454 gross tons; namely, 31,358,264 tons of Pennsylvania anthracite and 60,861,190 gross tons of other coals; and the value at the mines was: Pennsylvania anthracite, $70,556,094; bituminous coal, etc., $76,076,487; total, $146,632,581.

Iron.—The principle iron statistics for 1882 are as follows: Pig iron made, 4,623,323 gross tons; spot value, $106,336,429. Iron ore mined, 9,000,000 gross tons; spot value, $32,400,000. Domestic iron ore consumed, 8,700,000 gross tons; spot value, $31,320,000. Imported iron ore consumed, 589,655 gross tons. Total iron ore consumed, 9,289,665 gross tons. Total spot value of all iron and steel in the first stage of manufacture, excluding all duplication, $171,336,429. Anthracite consumed in all iron and steel works, including furnaces, 3,800,000 gross tons. Bituminous coal consumed in all iron and steel works, including furnaces, 6,600,000 gross tons. Coke consumed in all iron and steel works, including furnaces,3,350,000 gross tons. Charcoal consumed in all iron and steel works, including furnaces, 107,000,000 bushels. Limestone consumed as flux, 3,850,000 gross tons; spot value, $2,310,000.

For the first six months of 1883 the totals are as follows: Pig iron made, 3,352,019 gross tons; spot value, $47,040,380. Iron ore mined (and consumed), 4,500,000 gross tons; spot value, $12,375,000. Imported iron ore consumed, 185,000 gross tons. Total iron ore consumed, 4,685,000 gross tons. Total spot value of all iron and steel in the first stage of manufacture, excluding all duplications, $71,000,000. Anthracite consumed in all iron and steel works, including furnaces, 1,810,000 gross tons. Bituminous coal consumed in all iron and steel works, including furnaces, 3,140,000 gross tons. Coke consumed in all iron and steel works, including furnaces, 1,780,000 gross tons. Charcoal consumed in all iron and steel works, including furnaces, 38,750,000 bushels. Limestone consumed as flux 1,950,000 gross ton; spot value, $1,072,500.

Gold and silver.—The Mint authorities furnish the following statistics for 1882: Gold, $32,500,000; silver, $46,800,000; total, $79,300,000; or an increase of $1,600,000 over the output in 1881. For the first six months of 1883 the product is estimated at $16,250,000 gold,

$23,400,000 silver, and $39,650,000 total; the rate of production being assumed to be the same as in 1882.

Petroleum.—The production of crude petroleum in the oil fields of Pennsylvania and New York in 1882 was 30,053,500 barrels of 42 gallons each, worth, at an average spot value of 78⅞ cents per barrel, $23,704,698. During the first six months of 1883 the yield was 11,291,663 barrels, worth, at an average spot value of $1.00⅛ per barrel, $11,305,778. In addition to the quantitiy above stated, California produced in 1882 about 70,000 barrels.

Copper.—The production of copper in 1882 was 91,646,232 pounds, worth, at an average value of 17½ cents per pound in New York, $16,038,091. For the first half of 1883 the production is estimated at 58,000,000 pounds, worth, at an average price in New York of 14.65 cents per pound, $8,500,000. The spot value of the copper at the point of production is a matter which cannot be stated with any accuracy; nor was any attempt made to ascertain the tons of copper ore mined. In 1882, 3,325,000 pounds of bluestone, worth, $191,187, were made; and in the first half of 1883 the manufacture of bluestone is estimated at 1,662,500 pounds, worth $95,593.

Lead.—In 1882 132,890 net tons of lead were produced, worth, at an average value of $95 per net ton on the eastern seaboard, $12,624,550. For the first half of 1883 the production is estimated at 70,000 net tons, worth, at $90 per ton, $6,300,000. In this case, as with copper, it is impossible to state the average spot value of the lead, or the tons of lead ore mined. A very large proportion of the lead ore smelted is argentiferous, and is worked for its silver contents and not for the value of the lead, In the census year ending May 31, 1880, the amount of white lead corroded was reported at 123,477,890 pounds, worth $8,770,699.

Zinc.—The production of metallic zinc in 1882 was 33,765 net tons, worth, at an average value of 5.4 cents per pound in New York, $3,646,620. The production during the first six months of 1883 is estimated at 18,000 net tons, worth, at an average value of 4⅝ cents per pound in New York, $1,665,000. In addition to the spelter and sheet zinc made in this country, there is also a large manufacture of zinc oxide made directly from the ore. As in the case of copper and lead, it is impossible to fix an average spot value for the product, and the collection of statistics of zinc ore mined has not been attempted. In the census year 1880 the amount of zinc oxide manufactured, including that made from scrap zinc, was reported at 20,121,761 pounds, worth $766,337.

Quicksilver.—In 1882 the production of quicksilver was 52,732 flasks (of 76½ pounds each = 4,033,998 pounds), worth, at an average price in San Francisco of 36⅞ cents per pound, $1,487,537. During the first six months of 1883 the production was 22,740 flasks (= 1,739,610 pounds), worth, at an average price of 35¼ cents per pound, $613,213. During the year 1882 700,000 pounds of vermilion were made in the United States, having a total value of $315,000.

Nickel.—The production of pure grain nickel in 1882 was 277,034 pounds, worth, at $1.10 per pound, $304,737. There was also a production of 50 per cent. copper-nickel alloy containing 4,582 pounds of nickel, worth $5,040. The total nickel production was therefore 281,616 pounds, worth $309,777. The only nickel reduction works in the United States were closed during the first half of 1883.

Cobalt.—The value of cobalt ores and matte for 1882 was about $15,000. The amount of cobalt oxide made was 11,653 pounds, worth $32,046.

Manganese.—The production of manganese ore in 1882 was 3,500 gross tons, and the spot value at the mines, estimated at $15 per ton, was $52,500.

Chromium.—The production of chrome iron ore in 1882 was about 2,500 net tons, worth, at an average price of $40 per ton in Baltimore, $100,000. The spot value cannot be ascertained.

Tin.—A trifling amount of tin ore was mined in 1882 and the first half of 1883, and production of metallic tin began on a small scale towards the close of the latter period.

Antimony.—The production of metallic antimony, so far as ascertained, was 60 tons in 1882, worth about $12,000.

Building stone.—It is estimated that the value of the building stone quarried in 1882 was $21,000,000.

Brick and tile.—It is estimated that the total value of the brick and tile made in the United States in 1882 was $34,000,000.

Lime.—There were 31,000,000 barrels (of 200 pounds each) made in 1882, having a total spot value of $21,700,000 at the kilns.

Cement.—The amount of artificial Portland cement made in 1882 was 85,000 barrels, worth, spot, $191,250. Of the cements manufactured from natural cement rock there were 3,165,000 barrels made, worth, spot, $3,481,500. The total production of cement was 3,250,000 barrels, worth $3,672,750.

Clays.—Complete statistics of the quantity of fire and potters' clay mined in 1882 were not obtained. The value of the whiteware made was over $5,000,000.

Precious stones.—The spot value of the precious stones found in 1882, before cutting, was between $10,000 and $15,000; after cutting, between $50,000 and $60,000.

Corundum.—It is estimated that 500 tons were mined in 1882, worth on an average only about $12.50 per ton, crude and unground; total, $6,250. The value of the ground corundum manufactured during the same year was about $135,000.

Grindstones.—The value of the grindstones made from domestic rock in 1882 is estimated by leading dealers at $700,000.

Pumice stone.—There were 70 net tons quarried in 1882, worth about $1,750.

Phosphates.—The production of washed phosphate rock in 1882 by the land mining companies of South Carolina was 191,305 gross tons; spot value, $1,147,830. By the river mining companies, 140,772 gross tons; spot value, $844,632. Total, 332,077 gross tons; spot value, $1,992,462.

Marls.—In New Jersey, 1,080,000 net tons of marl were dug in 1882. The average spot value at the pits is 50 cents per ton, making the total $540,000. There was a small yield of marls in some of the Southern States, the amount of which has not been ascertained.

Gypsum.—The most complete statistics for 1882 are those of the output of Michigan, namely, 37,821 net tons of land plaster and 135,655 barrels (of 300 pounds each) of stucco. The manufacture of plaster-of-paris on the Atlantic seaboard was 525,000 barrels (of 250 pounds each), chiefly made, however, from Nova Scotia stone. Colorado produced 10,350 sacks (of 100 pounds each). The production of California and some other States was not ascertained.

Salt.—The amount of salt made in 1882 was 6,412,373 barrels (of 280 pounds each = 1,795,464,140 pounds), having a spot value of $4,320,140. During the first six months of 1883 the production is estimated at 3,206,186 barrels (= 897,732,080 pounds), worth $2,160,070, the rate of production being assumed to be the same as in 1882.

Borax.—The production in 1882 was 4,236,291 pounds, having a spot value at the works of $338,903. For the first half of 1883 the output is estimated at 2,800,000 pounds, worth, spot, $224,000.

Sulphur.—Complete statistics were not obtained. The production in the census year was stated at 1,200,000 pounds, worth $21,000.

Barytes.—The amount of crude barytes mined in 1882 was 20,000 tons, worth at the point of production $160,000. The value of refined and ground barytes manufactured from the crude product above stated was about $440,000.

Mica.—The quantity of merchantable mica mined in 1882 is estimated by leading dealers at 75,000 pounds, worth $250,000. The production is rapidly increasing.

Soapstone.—The amount quarried in 1882 is estimated at 6,000 net tons, worth $90,000 at the quarries.

Quartz.—The amount of quartz mined in 1882 for glass making and abrading purposes is estimated at 75,000 net tons.

Asbestus.—Amount mined in 1882, 1,200 net tons, worth $36,000 at the point of production.

Graphite.—Amount mined in 1882, 425,000 pounds, worth, crude, at the point of production, $34,000. During the first six months of 1883 the production is estimated at 262,500 pounds, worth $21,000.

Carbonate of Soda.—Over 1,600,000 pounds were produced in 1882 from native deposits.

Asphaltum.—The production in 1882 was 3,000 net tons, having a spot value of $10,500.

Alum.—No statistics. In the census year the amount of manufactured artificial alum was reported at 39,217,725 pounds, worth $808,165.

Copperas.—The amount of copperas manufactured in 1882 is estimated at 15,000,000 pounds, worth $112,500.

The production of the following-named substances was insignificant: Apatite, arsenic, bismuth, infusorial earth, iridium, lithographic stone, nitrate of soda, ozocerite, platinum, strontia.

No reliable statistics were obtained of the following substances: Buhrstones, chalk, feldspar, fluorspar, mineral paints, pyrites (for acid manufacture), sulphate of soda, talc (other than "soapstone").

None of the following substances are known to have been mined in 1882, or in the first half of 1883: Carbons, cryolite, rottenstone, wolfram.

Totals.—It is impossible to state the total mineral product in any form which shall not be open to just criticism. It is evident that the production statistics of such incongruous substances as iron ore, metallic gold and silver; the spot value of coal mined and the market value of metallic copper after having been transported hundreds of miles; the spot value of a crude substance like unground, unrefined barytes, and the value of a finished product like brick (in which the cost of manufacture is the leading item), such details cannot well be taken as items in a general summary. The statistics have been compiled with a view to giving information on those points which are of most interest and utility, and are presented in the form usual in the several branches of trade statistics. The result is that the values stated for the different products are necessarily taken at different stages of production or transportation, etc. Theoretically perfect statistics of mineral products would include, first of all, the actual net spot value of each substance in its crudest form, as taken from the earth; and yet for practical purposes such statistics would have little interest other than the fact that the items could be combined in a grand total in which each substance should be rated on a fairly even basis. The following groupings, therefore, are presented with a full realization of the incongruity of many of the items.

Values of the Metallic Products of the United States in 1882.

Pig iron, spot value	$106,336,429
Silver, coining value	46,800,000
Gold, coining value	32,500,000
Copper, value at New York City	16,038,091
Lead, value at New York City	12,624,550
Zinc, value at New York City	3,646,620
Quicksilver, value at San Francisco	1,487,537
Nickel, value at Philadelphia	309,777
Antimony, value at San Francisco	12,000
Platinum, value at New York City	1,000
Total	$219,756,004

Values of Some of the Non-Metallic Products of the United States in 1882 (*All Spot Values, except Chrome Iron Ore*).

Bituminous coal, brown cooal, lignite, and anthracite mined outside of Pennsylvania	$76,076,487
Pennsylvania anthracite	70,556,094
Crude petroleum	23,704,698
Lime	21,700,000
Building stone	21,000,000

Salt	4,320,140
Cement	3,672,750
Limestone for iron flux	2,310,000
Phosphate rock	1,147,830
New Jersey marls	540,000
Crude borax	338,903
Mica	250,000
Crude barytes	160,000
Chrome iron ore, value at Baltimore	100,000
Soapstone	90,000
Manganese ore	52,500
Asbestus	36,000
Graphite	34,000
Sulphur	21,000
Cobalt ore and matte	15,000
Precious stones, uncut	12,500
Asphaltum	10,500
Corundum	6,250
Pumice stone	1,750
Total	$226,156,402

Résumé of the Values of the Metallic and Non-Metallic Mineral Substances Produced in the United States in 1882.

Metals	$219,756,004
Mineral substances named in the foregoing table	226,156,402
	$445,912,406
Fire-clay, kaolin, potter's clay, common brick clay, terra-cotta, limestone used as flux in copper and lead smelting, iron ore used as flux in lead smelting, pyrites (for acid making), zinc white made directly from ore, marls (other than New Jersey), apatite, gypsum, tin ore, bismuth, arsenic, iridosmine, mill buhrstone and stone for making grindstones, lithographic stone, talc (other than "soapstone"), quartz, feldspar, fluorspar, terra-alba, chalk, crude mineral paints, nitrate of soda, carbonate of soda, sulphate of soda, native alum, ozocerite, mineral soap, strontia, etc.—certainly not less than	8,000,000
Grand total	$453,912,406

The grand total might be considerably reduced by substituting the value of the iron ore mined for that of the pig iron made; by deducting the discount on silver, and by considering lime, salt, cement, borax, etc., as manufactures. It will also be remarked that the spot values of copper, lead, zinc and chrome iron ore are much less than their respective values after transportation to market.

ON THE MANUFACTURE OF SULPHURIC ACID.

H. Pemberton, Jr., gives in the JOURNAL OF THE FRANKLIN INSTITUTE, 1883, vol. 115, p. 356, some results from the manufacture of sulphuric acid from brimstone, which illustrate the ratio between the nitre consumed and the chamber capacity; they are of interest, as they include a chamber system working with Gay-Lussac towers.

Pemberton calculates from the amount of the denitrated Gay-Lussac acid the quantity of nitre that passed through the chambers to every 100 parts brimstone, and finds 15·6 per cent. nitre, including 3·5 per cent. lost.

Hurter (1882, ccxlvi, 341) found in his theoretical examination of the sulphuric acid process, that the product of the chamber space and nitre consumed, approaches a constant figure, which represents the chamber capacity corresponding to one per cent. nitre consumed, Gay-Lussac towers not being used. The chamber capacity and nitrogen compounds present are indirectly proportional to each other, provided that the loss of sulphur is equally great, and the acid produced is of uniform concentration. When working with weak acid, a smaller chamber capacity is required. (See Wagners' *Jahresbericht*, 1882, p. 240.)

HURTER'S RESULTS (PYRITES ONLY.)

	Cubic feet capacity per lb. sulphur.	Nitre consumed per 100 lbs. sulphur.	Product of nitre consumed and chamber capacity.	Acid from 100 lbs. sulphur.	Sp. gr. of the acid.
A	32·3	10·0	323	431	1·55
B	29·8	11·2	334	392	1·65
C	21·5	12·0	291	345	1·65
D	22·3	13·7	305	386	1·65
E	22·8	9·5	217	405	1·50
PEMBERTON'S RESULTS (BRIMSTONE).					
1	26·8	10·0	268	……	……
2	29·8	9·0	268	……	……
3	35·7	8·0	285	……	……
4	19·2	15·6	300	……	……

The above results from Hurter are yearly averages, obtained from five important English works burning pyrites. Pemberton's results are derived from a set of chambers running on brimstone only, and in which, unfortunately, no positive statements in reference to loss in sulphur and concentration of acid are given, and which, therefore, do not allow of comparison with the much more certain results of Hurter. It is self evident that the constant for brimstone must be lower than that for pyrites.

In A and E the acid is much weaker; in A the yield is the best; in E the chamber capacity is the smallest. System 4 worked with Gay-Lussac with a loss of 3·5 per cent. nitre.—*Dingler's Journal.*

BRONZE FOR TELEPHONE LINES.

The careful investigation instituted by E Van Der Ven of the Teyler Foundation, on wires made of the metallic alloys, known as phosphor-bronze and silicon-bronze, are the more welcome on account of the discussions had, particularly at the Paris Electrical Congress, concerning the practicability of their use. The wires experimented with contained, according to chemical analyses made for him by M. Van Eyndhoven, in the case of the phosphor-bronze: copper, 95·5 per cent; phosphorus, 2·6 per cent., with small quantities of tin, manganese and silicic acid; in the silicon-bronze: copper, 92·2 per cent; silicium, 0·91 per cent., together with small quantities of tin, manganese and antimony.

The practical results of Dr. Van Der Ven's researches are, that phosphor-bronze has about 30 per cent. of the conducting power of copper, silicon-bronze about 70 per cent., while the steel as used in wires has only about 10·5 per cent. Comparing their tenacity, as also very carefully determined by him, with that of steel, he finds that a wire of the latter material, of 2 mm. diameter, with quadruple security and the conventional sag of .7 m., can have a stretch from pole to pole of 130 m., while the stretch, under the same conditions, of a wire 1 mm. in diameter would for phosphor-bronze be 106 m., for silicon-bronze 91 m. These alloys, with a diameter of 1·18 and of 0·77 mm. respectively, have the same electrical resistance as the steel wire of 2 mm. diameter. "The relatively short stretch which in general increases the expense of construction and maintenance, is less costly in cities, where at short distances the roofs of buildings offer points of suspension for telephone wires. It goes without saying that the bronze wires are preferable to those of steel, whose resistance demands a much larger section; the more, since the network of lines suspended in the air cannot be counted among the ornaments of a large city." To this result we may add the statement made by M. Bede at the Congress. A phosphor-bronze wire of .8 mm. (costing, too, the same as steel of .2 mm.) would, on account of its high elasticity, coil up before it has. fallen 4 m. from its original position—so rapidly that on breaking it would ordinarily not strike the ground, and hence would be less dangerous. On account of non-oxidation there is no loss of diameter.—*Musée Teyler and Electrotech. Zeitsch.* M B. S.

FRANKLIN INSTITUTE.

INTERNATIONAL ELECTRICAL EXHIBITION IN PHILADELPHIA, TO OPEN TUESDAY, SEPT. 3, 1884.

The attention of all persons interested in the generation and applications of electricity is respectfully invited to the Electrical Exhibition, to be held in Philadelphia, United States of America, commencing on Tuesday, Sept. 3, 1884, under the auspices of the Franklin Institute of the State of Pennsylvania for the promotion of the mechanic arts.

From the eminent reputation of this institution, coupled with the fact that the projected exhibition will be the first in America exclusively devoted to this important and progressive branch of science, the above announcement has attracted unusual interest throughout the United States, and the exhibition will undoubtedly afford an admirable opportunity of witnessing a representative display of American discovery and invention in electricity.

To increase its scientific and industrial importance, as well as to add to its attractiveness, it was determined, shortly after its inception, to give it an international character; and, the importance of the project having been properly represented to the Congress of the United States, an act was passed, which, having received the signature of the President of the United States, is now the law.

This official recognition provides for the admission into the United States, duty free, of all articles for exhibition only.

The text of this Act of Congress is as follows:

"WHEREAS, The Franklin Institute, of the State of Pennsylvania, for the promotion of the Mechanic Arts, propose to hold an exhibition of electrical apparatus, machinery, tools and implements, and other articles used in scientific and mechanical, and manufacturing business and investigations; and

"WHEREAS, It is deemed desirable to promote the success of such an exhibition by all reasonable encouragement, in order that it may be made useful for the promotion of knowledge; therefore be it

"*Resolved*, By the Senate and House of Representatives of the United States of America, in Congress assembled, that all articles that shall be imported for the sole purpose of exhibition at the exhibition to be held by the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts in the City of Philadelphia in the years 1883 or 1884, shall be admitted without payment of duty or customs fees or charges, under such regulations as the Secretary of the Treasury shall prescribe: *Provided*, That all such articles as shall be sold in the United States or withdrawn for consumption therein at any time after such importation, shall be subject to the duties, if any, imposed on like articles by the revenue laws in force at the date of importation: *And provided further*, That, in case any article imported under the provisions of this joint resolution shall be withdrawn (for) consumption, or shall be sold without payment of duty as required by law, all the penalties prescribed by the revenue laws shall be applied and enforced against such articles and against the persons who may be guilty of such withdrawal or sales."

It remains only to add at the present time that no effort will be spared by the Franklin Institute to secure a large and important representation of the progress of foreign countries, and that the most liberal provisions will be made to place European and American exhibitors on a fair and equal footing.

The subject of electricity and its applications, is at present attracting an unusual amount of attention, and the exhibition, side by side, of the best achievements of Europe and America, cannot fail to be in the highest degree instructive.

The necessary details respecting the classification of exhibits, applications for space, the regulations for the entry of articles for competition, advices as to the best modes of transporting articles intended for the exhibition, the arrangements for the reception and safe disposition of goods, and other needful information relating to the subject of the exhibition, will shortly be made public. A committee of the

Franklin Institute will be appointed to furnish information to exhibitors from foreign countries regarding the entry of goods intended for exhibition at the Custom House in Philadelphia. Intending exhibitors, desiring such information with promptness, are invited to communicate with the

Secretary Franklin Institute, Philadelphia, U. S. A.

Book Notices.

THE ORES OF LEADVILLE AND THEIR MODES OF OCCURRENCE, as illustrated in the "Morning" and "Evening Star" Mines, with a chapter on the Methods of their Extraction as practiced at those Mines. By Louis D. Ricketts B. S., *Ward Fellow in Economic Geology of the College of New Jersey.* With five plates and one colored lithograph. Princeton, 1883.

The first part of this work, or rather all except the descriptive part, including the methods of mining (called by the author "Methods of *Extracting* the Ores,") formed a thesis for the degree of Doctor of Science from the College of New Jersey.

It would be well for the standard maintained by the higher institutions of learning in this country if bequests for fellowships similar to the Ward fellowship, under which the work for this memoir was undertaken, were more common in our universities. By the terms of this fellowship its holder must devote a certain part of the year to the study of one or more of the mines in the West (if the writer be correctly informed, in Colorado.) Such studies are not only admirably adapted to test the thoroughness of the student in the many diverse branches of science which they involve, but they are of the greatest practical utility to all American and foreign geologists and mining engineers, since they reveal the methods by which important problems in mining have been solved under those conditions of labor, transportation, material and value which only obtain in our semi-settled domain.

The author acknowledges his obligations to Emmons, and presents his facts as further illustrations of the accuracy of the latter's theory of structure, in which he himself fully concurs, in all but a few minor particulars. After a short subdivision treating of the "General geology" and the "Position of the deposits," he proceeds to give in detail the "Geological structure at the mines." This is a very painstaking piece of work, very clearly illustrated by the horizontal projection of the two ore bodies of the mines mentioned in the title (Plate II); vertical sections through the shaft of the "Morning Star" (Plate III), and of the "Evening Star" (Plate IV).

The boundaries of the White Porphyry, Ore, Blue Limestone, Gray Porphyry (Blue Limestone), White Limestone and Quartzite which occur in the order given, proceeding from above downwards, are very clearly made out by the aid of careful observations, and references to the plates already referred to, as well as to a color plate (I), which gives in three figures, and in a manner striking to the eye, the irregular boundaries of the three various strata in vertical section. A detailed description of the rocks follows, accompanied by analyses of the two limestones and the white porphyry. The theory of ore currents is very succinctly and strongly stated. It is made very clear that the mode of occurrence of the ore is such as might have been produced by the filling up of the bed of a subterranean stream flowing, generally speaking, in contact with the present under surface of the white or upper porphyry. The minerals, both pure and impure, constituting the gangue are briefly stated and physically and chemically described. Under the head of the "Ores" the author for the first time makes an exception to the rule of extreme caution which he has imposed on all his statements. He thinks "there can be no doubt that the lead was all originally deposited in the limestone horizon as the sulphide."

Many experienced colleagues, both geologists and mining engineers, will not be able to follow him so far, nor does there appear any good reason why acid solutions charged with lead salts should not have deposited sulphates and chlorides and carbonates in the body of the limestone, as well as sulphides. It is also hazardous to assert that only "small amounts of all the metals were carried off in solution by the oxidizing waters," or that they were "to a large extent redeposited in the gangue." What may have been the extent to which these actions were carried we have no means of knowing, but there are no data at hand which will enable us to limit them, especially if the supply of waters charged with metal salts be supposed to have continued for a great lapse of time.

In the same chapter describing the Galena, Dr. Ricketts drops twice unconsciously out of the rigorously exact and scientific language which he has heretofore employed into the familiar parlance of the miners when he speaks of streaks of galena running through "black iron," and "surrounded by *iron*" (p. 31). Under the head of the "Chloride of Silver" he is somewhat disappointing to the reader in the sentences following that in which he says it is easy to explain where the silver missing from the carbonates has gone. He shows so many places where it has gone, *i. e.*, into the porphyry, the limestone and "the vein matter deep down in the current," as to render it extremely probable that a still larger supply than all may have gone into the seas which receive the drainage of the waters which he makes the transporting agent (though he does not mention them). Another slight omission seems to be the "remarkable deposition of cerargyrite in the white porphyry of the Evening Star. Except in the statement above and the incidental allusion to the silver in it, he does not give an adequate description of this very interesting phenomenon.

In describing the deposition of the vein materials, his theory of the "chemical interchange or actual replacement" seems unquestionably sound, but it is not clear how he intends the theory to be applied to the deposition of lead as the sulphide previously noted, nor in what form he supposes this metal to have arrived at its present place. The expression "oxidizing waters," which occurs on p. 45 and in various other places, does not specify clearly what kind of reaction on the carbonates of iron and manganese is meant. It is not stated what was probably the constitution of the "mineralized waters" carrying those metals, whereby they deposited them and took in return lime and magnesia to form with their acids more soluble salts.

The second part, which treats of the machinery and methods of mining, the construction of the plant, the cost of the items and the value of the product, is so complete and elementary in its descriptions as to constitute a valuable work of reference, and a text for the instruction of students in mining engineering.

Viewed as a whole, the memoir is highly creditable to the author, and to the college which crowned it by the highest reward for work done in its gift.

The style is generally clear, if not elegant; the printing neat, and the proof-reading generally carefully done, but there are a few not very important exceptions to the usual excellence in both these particulars, such as "prominant" (p. 21), "decomposition" (p. 38), the "more pure variety," etc.

The plates deserve to share the above commendation, though, in the judgment of the present writer, the colors in the color plate and the symbols on Plates III and IV to indicate white limestone might have been selected with more regard to the conventional uses of colors and lining for different rocks.

The pamphlet is a quarto; contains 68 pages of letter-press besides the four plates just alluded to, and is an important and valuable addition to our technical literature. P. F.

THE GEOLOGY OF CHESTER COUNTY, after the surveys of Henry D. Rogers, Persifor Frazer, and Charles E. Hall. Edited by J. P. Lesley. 1883.

In its typography, this volume is an improvement upon some which have preceded it, yet the errors are more numerous than they should be, and evidences of careless editing are not wanting. The well-known Chester Valley, besides that name, is called (p. 14) Limestone Valley of Downingtown (p. 16) Downingtown Valley, the Chester Valley as it is commonly called, (p. 98) Downington Valley, (p. 284) "the Limestone Valley in which is the King of Prussia."

(P. 179) "From the *Philadelphia* gneiss hills across to the Reading hills." Evidently the syenitic gneiss hills S. of the S. Valley hill are meant and not the Philadelphia gneiss of p. 40, etc. (P. 48) "The mica and hornblende *blackened* by iron."

A large part of the volume is made up of quotations from Rogers. Whatever doubts may have been cast upon some of Rogers' theories of structure, he stands preëminent as a most careful, conscientious observer of geological facts. These extracts coming, as they do, in this portable form, are valuable, but no effort seems to have been made to eliminate or point out errors; thus (p. 40), we find "Haddon," probably intended for Radnor, Callwell for Colwell, Matzan for Mattson, etc. (p. 100), nor do Rogers' observations seem to have been compared on the ground. This leads to what appear to be curious blunders on pp. 39 and 100. (P. 39), "The long belt of Serpentine starts in the *Talc-mica slates,* 1 mile S. E. of Paoli, more than 400 yards north of the contact of *gneiss* and *slate.*"

What Rogers wrote (I, p. 78) was, "Our line now crosses Crum Creek . . . and here the gneiss is in close proximity to the southern margin of the long belt of stratified serpentine, which originates in the *talcose primal slates,* about one mile S. E. of the Paoli, and more than one-fourth of a mile N. of the *gneiss* at that point."

Throughout C^4 the term "*talc mica slates*" is, with other terms, applied to the rocks of the S. Valley hill, while Rogers was writing of his *altered primal slates* which in C^4 are classed among the *gneisses,* both in the text (p. 283, etc.) and on the map. The map does not show the hydromica schists south of the serpentine, and on the contrary, on p. 60 we find, "The range of serpentine and limestone exposures limit it" (hydromica schist belt) "through Easttown," etc.

P. 100. "Passage beds, from the *talc mica slate* into limestone, are also recognized and described by Mr. Rogers, on p. 165, as visible at Callwell's (Colwell's) furnace at the mouth of Matzan's (Mattson's) run, opposite Conshohocken, on the Schuylkill, thus:

1. Talc slate, vertical, on the *N. slope* of the *South Valley hill,* then going *north.* 2. Limestone. 3. Talcoid nacreous slate 100′. 4. Limestone impure 50′. 5. Talcoid garnetiferous slate. Limestone, magnesian, say, 200 feet S. of Conshohocken bridge."

A glance at the map in C^6 will show that the north slope of the S. Valley hill is half a mile *North* of the Conshohocken bridge.

What Rogers really wrote (I, 165) is: "A transverse section at Caldwell's furnace from the *primal slates* into the auroral limestone displays: 1. Talc slate on the *north slope* of the *bounding ridge,*" and then as above. Now this *bounding ridge* was evidently the great gneissic ridge, with Rogers' altered primal slates forming its northerly slope, his section *ending* at the *southerly* slope of the S. Valley hill.

An inspection of the localities, or even a careful reading of Rogers, would have prevented such blunders.

P. 14. "South Valley hill, or hydromica schist belt . . . the Pennsylvania Railroad runs along the ridge from Radnor to Frazer, about 13 miles," but on p. 39, "West of Morgan's corner" (the old name of Radnor Station) "*gneiss,* massive, granitic," and p. 282, "The fragments of rock just N. of Radnor Station show a finely laminated gneiss." The table of elevations (p. 14) shows very clearly that for some distance W. of Radnor the railroad is descending the gneiss hill. P. 42, describing this gneiss belt, "Garnets are entirely absent," while on p. 286, speaking of the same belt in Easttown, "The whole of the southern part of the township is composed of syenitic granite . . . *with garnets.*"

The map of Mr. Hall, alluded to in the text, is omitted, except as a mere page sketch of no possible value in a complicated region, and that of Dr. Frazer, of a scale one inch to two miles, with the coloring in dispute, and one long line which "has no geological value whatever, but is merely a temporary expedient" (p. vi), is not a great advance over that published by Rogers twenty-five years ago. All the gneisses and mica schists south of the S. Valley hill, including the well-defined rock, Rogers altered primal, are embraced in one color. The trap (pp. 87 and 218) on the N. side of the serpentine, Easttown, is not upon the map.

In papers published in the *Proc. Min. and Geol. Sec. Acad. Nat. Sci.*, 1880–81, pp. 9 and 28, Theo. D. Rand asserted that the serpentine in Radnor and Easttown, instead of outcropping in lines which, if prolonged, would meet, as mapped by Hall,* and by Dr. Frazer, in the present volume, had an echelon structure, the strike being from S. 40 W. to S. 60 W., while a line joining the exposures would be nearly E. and W., and called attention to Rogers' description of a similar structure of the trap dykes north of the serpentine quoted in C^4, p. 87. A map of the outcrops was published with the text. If these outcrops are as stated, the fact is of interest; if they are not, the error should have been corrected. In a criticism of the map by Dr. Frazer, in 1883,† no allegation of error in this particular is made.

In the same papers are described outcrops of a sandstone which Mr. Rand thought was identical with the eurite of Barren Hill, etc., admitted to be Potsdam, and also a sandstone resembling the Potsdam of the North Valley hill, found on the north slope of the South Valley hill. These rocks do not appear to have been examined, but the broad statement is made, p. 34: "The quartzite failed altogether on the south side of the valley;" and page 124: "But no Potsdam sandstone has been detected anywhere along the south edge of the limestone area. Rogers did not overlook the sandstone along the south side of the Chester valley (Vol. I., p. 166). The other exposures were probably not visible when his survey was made.

It is doubtless true, as Prof. Lesley states in his letter of transmittal, that Dr. Frazer has studied the region with thoroughness, and has recorded a large number of observations, taking into consideration the very limited time devoted to the region—three days to a township (p. xx.); but that this report adds much to our knowledge of the region may well be doubted. In the letter of transmittal may be found an explanation. "Little more can be said than that the first geological survey did something to reveal the structural geology of the Philadelphia Baltimore belt, and that the second geological survey has added its mite to the revelation, but that a great deal more light must be thrown upon it before we can congratulate ourselves upon a proper and satisfactory knowledge of it. . . . . We have an abundant knowledge of all the kinds of rocks in the region . . . . merely as minerals . . . . and there is quite as much information respecting their localities in Delaware and Chester ounty as there is respecting the localities of coal in any western county of the State. It would be quite as absurd to ask of the . . . . survey . . . . to do the work of opening up continuous outcrops of these minerals (and we must presume of mapping those that are known) as it would be to ask the survey to prove by actual digging the continuous outcrops of the Pittsburg . . . . or the Sharon coal beds. What the State provides through the geological survey is such general investigation of the field, such an examination of localities as will result in a *just and practical understanding of geological structure.*"

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* *Proc. A. P. S.*, vol. xviii., p. 105.

† *Amer. Nat.*, xvii., No. 5, p. 523.

In so complicated a region how is this end to be attained without exactly what Prof. Lesley says it is absurd to ask? His admission that it has not been attained or even approached renders the comparison hardly fair between a region in which the leaves of the geological book are as if it had been struck on its edge with a steam hammer, with one in which they are almost as smooth and regular as in a book fresh from the binder's hands.

Admitting the difficulty of the region, admitting the fact that the rocks vary greatly, and that a determination of geological age must be left to the future, is it not the only true plan to delineate on a map of ample scale the formations *as they are*, much as one would in other branches of science plot observations upon a series of abscissæ and ordinates, hoping thereby to get a curve and discover a law? Is there any better way? T. D. R.

Electric Properties of Collodion.—J. Seure states that collodion, in thin sheets, is negative towards all other bodies. In interpreting the therapeutic effects of collodion, account should be taken of its electric power. Gutta percha, when it is electrified, presents modifications which are analogous to those of collodion.—*Comptes Rendus.* C.

Electric Furnace.—The electric furnace possesses two great advantages—the temperature which can be produced is only limited by the refractory resistance of the crucible, and the heat is developed in the materials which are to be melted, without first traversing the recipient. Six pounds of forged iron were submitted for twenty minutes to the action of the arc, and the metal was then poured into a mould. It was found to be crystalline and could not be forged. This difficulty may be remedied by adding a little manganese before pouring out; but the reason of this action is not understood. Three-quarters of a pound of copper were melted in charcoal dust for an hour, at the end of which time all but three-quarters of an ounce had been vaporized. The persons who were present did not perceive any disagreeable effects from the atmosphere which they were obliged to breathe. Eight pounds of platinum were entirely melted in about a quarter of an hour. A half pound of powdered tungsten was submitted to the action of the electric arc, in a clay crucible. Very dense fumes escaped, and a cavity about a half inch deep formed at the summit. The metal appeared to have been melted to only a very slight depth below the cavity. The unmelted portion was covered with very beautiful crystals, which, when examined by a microscope, were found to be prismatic, but they were not very uniform. The crystals were evidently formed by the slow cooling of the distilled vapor. Experiments were tried with various other metals, showing that the quantity of any given metal which can be completely melted in an electric furnace, and the time required for the fusion, depend upon the interval between the point of fusion and the point of vaporizing, as well as upon the thermal conductibility of the metal. Thus it happens that platinum is melted much more easily than steel, and in a much greater quantity, for the same expenditure of energy.—*L'Electricien,* Jan. 1, 1883. C.

Rapid Formation of Mineral Veins.—Dr. Fleitmann has found that the formation of mineral veins requires much less time than has usually been supposed. About two years ago he filled a ditch with clay which contained iron. Having had occasion to open the ditch again, he discovered, to his great surprise, that the clay had entirely changed its character, and had become white. Moreover, it was divided in various directions by fissures, with sections varying from $\frac{1}{25}$ to $\frac{1}{6}$ of an inch, which were filled with compact iron pyrites. He supposes that the oxide of iron in the clay was changed into sulphate of iron by contact with water which contained sulphate of ammonia.—*Les Mondes*, March 4, 1883. C.

Ingenious Rat Trap.—Capt. Godreuil had a ship infested with rats, which devoured his provisions and his rigging. He took an empty flour barrel, leaving only three hoops, one at the top, one at the bottom, and one in the middle, so that the rats could not climb up on the outside. He placed above it a cover, with a diameter a little less than that of the barrel, and supported it on two pivots, so that it would rock under the least weight. Under the centre he placed a hook, to which he suspended a bit of toasted bacon; finally, a strip of plank, forming an inclined plane, extended a little above the barrel. When the rats reached the top of the plank they leaped upon the cover, which rocked under their weight, and they fell to the bottom of the barrel, from which they could not escape, the staves being closely joined, and smeared with tallow.—*Les Mondes*, Feb. 10, 1883. C.

Bridge Travel in London.—Proposals having been made for building a new bridge over the Thames, statistics have been collected to show the amount of travel over the present bridges. The following table shows the average daily travel over a few of the principal bridges:

London	110,525	pedestrians,	22,242	vehicles.
Black Friar's	79,198	"	13,875	"
Westminster	44,460	"	11,750	"
Waterloo	32,815	"	10,370	"
Southwark	25,507	"	3,340	"
Vauxhall	17,828	"	5,453	"
Charing Cross	16,130	"		
Chelsea	14,500	"	2,338	"
Battersea	10,260	"	1,342	"

The addition of the other bridges gives a total of 384,042 pedestrians, and 75,325 vehicles.—*Dingler's Jour.*, Jan. 24, 1883. C.

Factory Chimneys.—It is well known that the round form is the best for the chimneys of factories and workshops. It facilitates the escape of the smoke, and gives less hold for the wind, besides requiring less material for construction. Round chimneys, however, are more difficult to build, so that in some places the want of workmen who are skilled in this kind of construction leads to the adoption of a square or octagonal section. In order to facilitate the erection of round chimneys, M. Houzen, of Nüremberg, prepares materials cut in the form of wedges, corresponding with the radius which the chimney is to have, so that the construction presents no kind of difficulty.—*Chron. Industr.*, Feb. 18, 1883. C.

Spectroscopic Estimates of Atmospheric Absorption.—Cornu has been led, by his investigations of the atmospheric absorption of the ultra-violet rays, to examine the relation between that phenomenon and the absorption of the visible rays. His attention was especially directed to Brewster's dark bands, which are generally known as telluric rays, the intensity of which increases with the thickness of the atmosphere which they traverse. He finds that the amount of absorbing matter may be estimated by the sines of the altitude from the sun at which a telluric ray has the same intensity with a metallic ray. Hence may be deduced a very simple method for estimating, at any moment, the total amount of vapor which exists in the atmosphere.—*Comptes Rendus*, Nov. 6, 1882. C.

Azotine.—M. Heddebault has discovered a method of preparing soluble wool from tissues in which wool and cotton are combined. When subjected to a current of superheated steam, under a pressure of five atmospheres, the wool melts and falls to the bottom of the pan, leaving the cotton, linen, and other vegetable fibres, clean and in a condition suitable for paper making. The melted wool is afterwards evaporated to dryness, when it becomes completely soluble in water and is called azotine. The increased value of the rags is sufficient to cover the whole cost of the operation, so that the azotine is produced without cost. It contains all its nitrogen in a soluble condition and can, therefore, be compared to dried blood, which is worth 2.50 francs per kilogramme of nitrogen. M. Ladureau regards this discovery as one of great interest for agriculture and mechanical industry.—*Soc. Industr. du Nord.* C.

Magnetism of Steel at Different Temperatures.—Prof. Poloni has been experimenting upon the influence of heat on the permanent magnetism of steel. He finds that the diminution of magnetic intensity, by the increase of temperature in the steel bar, has no rigid relation to the increase of electric resistance in the metal itself. Indeed, while the permanent magnetism diminishes with increasing rapidity up to a temperature of about 200° (328°F.), and then less rapidly up to 300° (508°F.), becoming inappreciable at red-heat, the electric conductibility of the iron diminishes uniformly with the increase of temperature.—*Chron. Industr.*, Jan. 7, 1883. C.

Electric Currents Produced by Nitrates.—M. Brard has communicated some investigations to the French Academy, which give the following results: 1. On plunging a red-hot carbon into a bath of melted nitrate an energetic current flows from the bath into the exterior circuit. 2. The melted nitrates become very fluid, and like greasy bodies lubricate the heated bodies with which they come in contact. 3. In order to obtain a current it is not necessary to plunge the carbon into the nitrate bath, but it suffices to place a metal capsule containing some grains of the melted nitrate upon the burning carbons. M. Brard is continuing his experiments with a view to apply them practically in the production of light and heat.—*Les Mondes*, Jan. 13, 1883. C.

Photographs of the Great Comet.—Six photographs of the late comet, which were taken at the observatory of the Cape of Good Hope by D. Gill, were sent to the Paris observatory and presented to the Academy by Admiral Mouchez, who pronounced them the finest that he had seen. The stars in the centre of the image are reduced to a point of remarkable sharpness, in spite of the very long duration of the exposure, which amounted to 140 minutes for the sixth negative. More than fifty stars are seen through the tail of the comet. The slight increase of diameter, which is observed in the stars remote from the centre, is due to the employment of an apparatus with too short a focus. The fine result is explained by the well-known skill of the photographer and the purity of the South African sky. The success of the experiment encourages the hope that it will soon be possible to make excellent celestial charts by photography.—*Comptes Rendus*, Dec. 26, 1882. C.

Absorption by the Humors of the Eye.—M. de Chardonnet finds that most of the rays of the solar spectrum traverse the cornea and the vitreous humor, but the spectrum of the crystalline lens corresponds exactly to the visible spectrum, and he thinks that lens has the physiological function of intercepting all the ultra-violet rays. He was, therefore, led to inquire whether our failure to see those rays is owing to an insensibility of the retina or to the fact that the rays do not reach it. Dr. Saillard furnished him with two subjects, who had had the crystalline lens removed in operations for cataract. The retina, in both cases, was as sensitive to the ultra-violet rays as to the visible rays.—*Comptes Rendus*, Feb. 19, 1883. C.

Age of Vegetables.—It is generally thought that the age of trees may be ascertained by the number of concentric ligneous layers, each layer corresponding to the growth of a year. This principle is not applicable to tropical and equatorial trees, as is shown by the following fact. M. Charencey visited the ruins of Palenque, in Mexico, in 1859 and in 1881. On one occasion he cut off the branch of a shrub, which he judged by its size to be about eighteen months old, but he found eighteen concentric layers. On his first expedition his party cut down several trees, in order to get at the pyramid. New shoots have since grown, which must, of course, all be of the same age, twenty-two years. On one of them M. Charencey counted 230 concentric layers.—*Les Mondes*, Feb. 10, 1883.

Modifications of Glass at Moderate Temperatures.—Messieurs Crafts and Pernet have presented some recent communications to the French Academy, relatively to the changes which thermometers undergo when they are heated for a long time. In manufactories of printers' ink, where oils are heated to a temperature of 270° (538°F.) for many days, the most accurate thermometers often become so changed as to indicate errors of ten or more degrees. J. Salleron calls attention to similar changes at much lower temperatures. The areometers which are employed in sugar refineries where molasses is treated by osmosis, are plunged for many days in liquids which are heated to 95° (203°F.). Although this temperature is below the boiling point of water, it is sufficient to completely modify the areometers and to soften the glass enough to make them untrustworthy.—*Comptes Rendus.* C.

Cement for Glass.—A concentrated solution of bichromate of potash and glue makes an excellent cement for repairing articles of broken glass. After covering the fractured surfaces with this solution they are brought together and exposed to the action of the sun. This cement resists boiling water.—*Gaceta Industrial,* March 10, 1883. C.

Detection of Wood Fibres in Paper.—As wood changes under the influence of the air, growing brown and consequently diminishing the durability of the paper in which it has been employed, it is of great importance, both for the dealer and for the consumer, to be able to ascertain whether a given sample of paper contains woody fibres or not. For this purpose a solution of sulphate of aniline, or a mixture of one part sulphuric acid, three parts nitric acid may be employed. Either of these solutions produces immediately a yellow color upon the paper if it contains wood, the depth of the yellow shade increasing as the proportion of wood increases.—*Chron. Industr.,* Feb. 25, 1883.

Relation of Electromotive Force to Velocity of Rotation.—In his recent lectures at the College of France, Maurice Levy has given equations which rigorously define the electric field and the magnetic field of a dynamo-electric machine in its permanent state. Although the equations cannot be integrated, he has deduced many consequences, among which he calls especial attention to the following: The electromotive force of a dynamo electric machine is not, as has been commonly thought, proportional to the velocity of its coils; it can only be expressed by an infinite series, arranged according to the integral powers of that quantity.—*Comptes Rendus,* Nov. 6, 1882. C.

Hollow Magnets.—While Preece has found that there is no difference in the conducting power of lightning rods of various forms, Holtz has concluded that solid steel bars do not form so good permanent magnets as tubes, because the core acts as an armature joining the two poles. In experimenting to test his hypothesis, he magnetized rods and tubes to saturation, and found that the magnetism of the tube showed an excess of more than 50 per cent. After waiting six months, he subjected the same magnets to new tests, in order to find which retained the magnetism best. He found that the magnetism of the solid was to that of the hollow magnets, in one case as 1 : 2·5, in another as 1 : 2·9.—*Wied. Annalen* C.

Tail of the Great Comet of 1882.—Terby, in concluding the report of his observations upon the aspect and positions of the last great comet, concurs in the opinion of Cruls, that the appearances may be explained upon the hypothesis of a triple tail, of which the three elements were almost wholly superposed in September, and were gradually unfolded before terrestrial observers during the months of October and November. One of these tails was directed almost exactly in the line of the prolonged radius vector, as in the case of Donati's comet. The others were more curved.—*Bul. de l'Acad. de Belg.*, 1883. C.

Spectral Lines of Cruls' Comet.—Cruls, in a letter to Faye, gives the mean of numerous micrometric measurements of the spectral lines, and also of the lines which were given by the blue flame of a Bunsen burner in which he had introduced chloride of sodium:

Comet.	Burner.
38t·15	37t·86
42 ·12	41 ·60
50 ·43	50 ·00
62 ·58	62 ·30

The measurements are given in turns of the micrometer (t). The spectrum of the tail was like that of the nucleus, but the lines were much fainter.—*Comptes Rendus*, Nov. 6, 1882. C.

Displacement of Spectral Lines in the Late Comet.—In examining the comet of 1882, by a spectroscope of a single prism, Thollon and Gouy were able not only to prove the existence of the bright lines of sodium, but also their displacement towards the red, a displacement which they estimated at $\frac{1}{4}$ or $\frac{1}{5}$ of the interval between the two sodium lines D_1 and D_2. They concluded that the comet was removing from the earth at that moment with a velocity of from 61 to 76 kilometres per second. They looked with great interest for an opportunity of verifying their conclusions, but nothing was then known regarding the comet's orbit. M. Bigourdan has since found that the comet was then moving with a mean velocity of 73 kilometres per second. This accordance shows the certainty of spectroscopic indications in such cases. It also shows that the vapors of sodium, which surrounded the cometary nucleus, followed the same path and made part of the constituent elements of the comet. It also confirms, in a remarkable manner, the law of the change of wave lengths produced by the movement of the luminous body.—*Comptes Rendus*, Feb. 5, 1883. C.

Thickness of Electric Layers.—M. Lippmann has pointed out some numerical applications of Helmholtz's theory of double electric layers. He shows, at first, that the hypothesis of the double layer conducts to a parabolic relation of the second degree, between the capillary tension and the difference of potential; experiment verifies this deduction. Admitting the hypothesis of the double layer, its thickness may be calculated by means of the well-knwn formula which gives the capacity of a thin layer as a function of its thickness. The thickness is thus found to be $\frac{1}{35000000}$ of a millimetre, which represents the distance between the mercury and the superposed water.—*Chron. Industr.*, Jan. 7, 1883. C.

Light Motors.—In an excellent article which appeared in a late number of the *Aéronaut*, David Napoli, President of the Société de Navigation Aérienne, examines the comparative desirability of steam and electric motors for propelling long balloons. He found that a twenty-horse steam engine, working for ten hours, would consume 200 kilogrammes of coal and 1,400 kilogrammes of water. An electric engine of twenty-horse power, with all its supplies for ten hours' service, would weigh about 1,400 kilogrammes, which is less than the bare consumption of material in the steam engine, leaving out of the question the weight of the generator and of the mechanism of transmission.—*Chron. Industr.*, April 15, 1883. C.

Explosion of an Open Kettle.—At a factory in Neusalz, a large cast iron wash kettle was used to hold water, into which melted iron was allowed to flow, in a moderate stream, for making iron shot. On October 23, 1882, one of the workmen by mistake allowed the iron to flow too rapidly. There was a sudden development of steam, which threw out a part of the water, frightening the laborer and causing him to drop his ladle, so that about 20 kilogrammes (44 pounds) of melted iron fell at once into the water. There was an immediate rapid outburst of steam and a loud explosion, which shattered the kettle into fragments, tore up the wood work, threw the workman nearly eight feet backwards and broke his right leg. Only very small pieces of the kettle were found where it stood; some of them were thrown to a distance of about fifty feet.—*Dingler's Jour.*, March 7, 1883. C.

An Arabic Celestial Globe of the Eleventh Century.—In the philosophical cabinet of the Royal Institute of Florence, many of the instruments of Galileo and other students of astronomy and physics are preserved. Among them is an Arabic celestial globe, of which F. Meucci has published an interesting description. It has not been long in possession of the Institute and no one suspected its antiquity until recently. The one which is in the Borgian Museum, at Velletri, which was described by Assemani, in 1790, and which dates from the year 1225, has hitherto been regarded as the oldest. There are two others of the same century, one of A. D. 1275, owned by the Royal Asiatic Society of London, the other of A. D. 1289, in the mathematical Saloon at Dresden. There are also two, one owned by the Royal Astronomical Society of London and the other by the National Library of Paris, both of which are without date. Meucci's curiosity was first awakened by observing that the longitude of the stars showed that the globe must have been constructed about the year 1075. On closer examination, he found an Arabic inscription around the Antarctic Circle, which he submitted for translation to the learned orientalist, Prof. F. Lasinio. He presented a note to the Society, in a meeting which was attended by the Emperor of Brazil, in which he stated that the inscriptions were in cufic characters, and that the globe "was made by Ibrahim Ibn Said as-Sahli and his son Muhammad; the work was finished in Valenza, in the beginning of the month of Safar, in the year 473 of the Hegira (corresponding to the 22d of July, 1080)." The diameter of the globe is 209 millimetres (8·23 inches). It is composed of two hemispheres of brass, soldered together, and it gives the arrangement of stars and constellations which was adopted by Ptolemy. Among the Southern constellations, the Cup (Cratera), which should have been placed between the second and third coils of the Hydra, is wanting; all the other constellations are very well engraved. The positions of 1015 stars are given and their magnitude is well marked, inasmuch as every point, which is engraved to give the precise position of a star, is the centre of a little circle, which diminishes in diameter from the first to the sixth magnitude. The two circles of the equator and the ecliptic are divided by means of little lines into 360 degrees, every fifth degree being marked by cufic numeral figures. The zero of the equator is at its intersection with the ecliptic, in the beginning of the sign Aries. Twelve great circles of declination, lightly engraved, divide the ecliptic into its twelve signs. Forty-seven constellations are represented, 21 of which are in the Northern hemisphere, 12 in the Zodiac, and 14 in the Southern hemisphere. A heart-shaped curved line incloses the six stars near Aquilla, which represent, upon our celestial globes, the constellation of Antinous. This constellation and that of Berenices' Hair were introduced by Tycho Brahe, in the 16th century. On this globe, as upon other Arabic globes, the figures face the observer instead of looking towards the centre of the sphere. Therefore the stars which are upon the right side of a constellation on our globes are on the left side on the Arabic globes, and *vice versa.—Pub. del. R. Instituto*, 1878. C.

Charlemagne's Bridge over the Rhine.—Near the close of the eighth century, Charlemagne ordered the construction, over the Rhine, of a bridge resting on twenty-eight buttresses. The bridge was struck by lightning and burnt to the level of the water. German engineers are now removing the remains of the old structure, on the Mayence side. They have already taken out fifty piles, with the lengths of five or six meters (5·468 to 6·562 yards). The wood, which is nearly eleven hundred years old, is so well preserved that it can still be used in building; the iron, which was riveted to the posts, can also be used, since it is covered only with a thin layer of rust.—*Chron. Industr.* C.

The Eden Theatre of Paris.—This building, constructed at great expense in one of the richest quarters of Paris, near the left of the new Opera House, presents a general effect of decoration surpassing in splendor all that has hitherto been undertaken in Paris or other capitals. The facade of Rue Boudreau is built of Palotte stone, of a creamy whiteness, with columns of Scotch sandstone, Venetian mosaics, huge elephants' heads, sheaves of gilded zinc, and pyramids crowning all the upper portion; the six grand lanterns of forged iron with colored glass, suspended at the height of the cornice of the third story, brilliantly illuminate the whole ground floor, the streets and the neighboring fronts. The general effect of the Indian architecture is heavy, and violates many of the rules of delicate architectural taste, but the richness of the ornamental details, especially when the building is illuminated, gives an impression of fairyland.—*Lumière Electrique*, April 14, 1883. C.

Chemical Applications of Electricity.—Among the electrical processes which encourage great hopes for the future, those which bear upon the industry of chemical products and the preparation of metals have been somewhat overlooked. It is well to remember that the dynamos, in the estimation of their inventor, were designed to take the place of batteries in galvanoplasty, before they were applied to the unexpected uses of lighting and of mechanical transmission. Industrial chemistry will undoubtedly draw advantages from the resources which are offered by the electric current. The last international electrical exhibition showed how to prepare metals chemically pure, to extract the precious metals from their salts or their alloys, to treat ores, and to form some special combinations for dyeing. While the French houses were spreading before our eyes the wonders of artistic galvanoplasty, Létrange published his researches upon the preparation of zinc, Wohlwill displayed a wonderful collection of metals deposited electrically, and Goppelsröder, with the modesty of a savant, presented specimens of colors obtained by electrolysis.—*L'Electricien*, No. 40. C.

Electric Transmission of Force.—It was at first reported that Marcel Deprez had succeeded in transmitting 60 per cent. of the mechanical efficiency of a motor, by electricity, from Miesbach to Munich. It was afterwards found that the industrial or economical transmission differs considerably from the electric. The electric transmission, as measured, appears to have varied from 50 per cent. to something more than 60 per cent., while the industrial oscillated between 25 per cent., in the first experiment, and something more than 35 per cent. in the second. Deprez's experiments at the Munich exhibition were very beautiful from a scientific point of view, and they seem to have shown that we may reasonbly hope to transport to a great distance more than a fourth of the force produced by a motor; but such a transmission, with a few exceptional cases, does not offer any great practical advantage from the adoption of the new system. It may be useful in rendering available the power of great waterfalls, and science cannot be too grateful for the patient researches with which Deprez devotes himself to the construction of machinery for that purpose.—*L'Electricien*, No. 40. C.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVI. OCTOBER, 1883. No. 4.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

THE COMMERCIAL AND DYNAMIC EFFICIENCIES OF THE STEAM ENGINE.

By PROF. ROBERT H. THURSTON.

[American Association for Advancement of Science; Minneapolis Meeting, August, 1883.]

The writer, at the meeting of 1882 of the American Association for the Advancement of Science, in a paper on a newly discovered "Absolute Limit to Expansion in the Steam Engine,"* gave what he has called the "General Equation of Steam Engine Efficiency."

In that equation it was assumed that the annual expense chargeable to, or variable with, the cost of engine maintenance and operation could be reckoned per unit of volume of steam cylinder without serious error. Although this is often, and with large engines generally, true, and although it may not lead to appreciably erroneous results, it may yet be sometimes advisable to adopt the more general formula about to be given and which may be made as general and as exact as may be desired.

In the equation above referred to, an approximate form was adopted —making the denominator variable with variation of the waste by cylinder condensation and leakage, instead of the second term in the numerator—for the purpose of obtaining a more manageable, although less precise expression.

The equation to be here given may be used when greater precision and a wider range of application is thought desirable than could be secured with the equation already given for general use in earlier papers.*

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* Trans. Am. Assoc. for Adv. Science, 1882; JOURNAL OF THE FRANKLIN INSTITUTE, September, 1882.

Adopting the nomenclature assumed in the earlier treatment of the subject, but making the "costs of engine" vary as a function—$r^m v_1^m$—of the size of steam cylinder or volume traversed by the piston per stroke, and the ratio of expansion.

$A =$ total annual cost of all items variable with size of steam cylinder and per unit of volume; *i. e.*, "cost of steam."

$r^m v_1 = v_2^m =$ rate of variation of such costs with variation of size of cylinder; such that

$A r^m v_1^m = A v_2^m =$ total annual costs so variable for an engine of volume: $v_2 = r v_1$;

$B =$ total annual cost, per unit of volume of steam supplied, of all items variable with such volume; *i. e.*, with "cost of steam;"

$C =$ total of all annual costs invariable within the range of the problem;

$a = \frac{v_s}{v_2} =$ ratio, volume of steam supplied at full stroke divided by volume of cylinder—a quantity always greater than unity.

$r^q =$ the measure of the variation of this relation with variation of the expansion-ratio; so that

$a B r^q v_1 =$ total annual cost of all items so variable for any engine supplied with a *net* volume of steam v_1 per stroke and working with a ratio of expansion r.

$K =$ total annual cost of all items in doing total work;

$n =$ index of the expansion curve, in the equation $p v^n = p_1 v_1^n =$ constant;

$p_1 =$ initial steam pressure;

$p_b =$ total back pressure, including all useless resistances;

$p_3 =$ back pressure in the steam cylinder;

$R =$ number of revolutions of crank per annum;

$W =$ work done per stroke by the given engine under the assigned conditions;

Also make the values

$$M = \frac{A}{Ba} \quad ; \quad N = \frac{A + C}{Ba}.$$

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* Trans. Am. Soc. Mech. Eng'rs, 1882; JOURNAL OF THE FRANKLIN INSTITUTE, February to July, 1882.

The annual cost of doing the given work will consist of the sum of the annual costs variable with size of engine, $A\, r^m\, v_1^m$; the annual costs variable with steam supply, $a\, B\, r^q\, v_1$; and the invariable cost, C; *i. e.*,

$$K = A\, r^m\, v_1^m + B\, a\, r^q\, v_1 + C \tag{1}$$

which is a minimum when the variable part is a minimum, and this latter is a function of the work to be done and of size of engine taken to do that work.

We may thus take up the problem of the designer and of the buyer of a steam engine:

Given: The work to be done by an engine.

Required: The ratio of expansion at which the demanded power may be furnished most economically.

This problem being solved, and this ratio of expansion being determined, the mean pressure becomes known and the necessary size of engine is easily calculated.

The work done per stroke is

$$W = p_1 v_1 \frac{n - r^{1-n}}{n-1} - p_b\, r v_1 = \text{Const.} \tag{2}$$

It is necessary to "minimize"

$$\frac{K}{2\,R\,W} = \frac{A\, r^m\, v_1^m + B\, a\, r^q\, v_1}{2\,R\,W} = \frac{A\, r^m\, v_1^{m-1} + B\, a\, r^q}{2\,R\left(p_1 \frac{n - r^{1-n}}{n-1} - p_b\, r\right)} \tag{3}$$

If $M = \frac{A}{Ba}$; we may take

$$u = \frac{M\, r^{m-1}\, v_1^{m-1} + r^{q-1}}{n\, r^{-1} - r^{-n} - (n-1)\frac{p_b}{p_1}} \tag{4}$$

and, making $\frac{du}{dr} = o$, we obtain a minimum, and "Maximum Commercial Efficiency" when

$$\frac{Mmn\, v_1^m r^{m-1} - M(m+n-1)\, v_1^m\, r^{m-n} + q\, n\, v_1 r^{q-1} - (q+n-1)\, v_1 r^{q-n}}{M\,(m-1)\,(n-1)\, v_1^m\, r^m + (n-1)\,(q-1) v_1\, r^q} = \frac{p_b}{p_1} \tag{5}$$

When $m = 1$, as in the usual case, nearly, cost of engine becomes directly proportional to cylinder volume, and

$$r^{-1} - \frac{q + n - 1}{q\,n} r^{-n} + \frac{M}{q} r^{-q} - \frac{M}{q} r^{-q-n} = \frac{(n-1)(q-1)}{qn} \frac{p_b}{p_1} \qquad (6)$$

When $q = o$ and $a = 1$, we have the ideal case of the perfectly non-conducting cylinder, and

$$r^{-n} - M \frac{n - n\,r^{1-n}}{n - 1} = \frac{p_b}{p_1} \qquad (7)$$

When seeking "Maximum Efficiency of a Given Plant" that ratio of expansion is determined at which a given engine in place can do work with maximum economy, *i. e.*, the maximum work which it should be expected to do. Then we have simply to substitute N for M in the above expression. The quantity of power thus determined could, it will be found, be done, however, by a somewhat larger engine operated at a somewhat higher ratio of expansion than is obtained by the solution of this second problem.

When M and N are made zero, the ratio of expansion determined is that giving "Maximum Efficiency of Engine" and

$$r^{n} = \frac{p_1}{p_b} \qquad (8)$$

Finally, when, in this last expression, p_b is replaced by p_3, the back pressure in the cylinder, we have

$$r^{n} = \frac{p_1}{p_3} \qquad (9)$$

and the ratio of expansion is determined which gives "Maximum Efficiency of Fluid."

Hoboken, N. J., January 1883.

The Improvement of Wells.—Emilio Bianchi has turned his attention to the impurities of surface drainage which so often contaminate well water. He proposes to remove all wooden pipes and casings, and to substitute tubes of cement, which can be made at small cost, and which can preserve the water in perfect purity. These pipes can be formed of a series of tubes, united together by water-tight joints, so as to shut out lateral and superficial infiltration, and secure an abundant supply of pure water, if the well is sunk deep enough. In extreme cases, he proposes, after reaching a certain depth, to place a diaphragm or filter, made of béton and carbon, so as to oblige the water of the well to pass through it.—*Il Politecnico*, Sept., 1882. C.

THE STEAM ENGINE INDICATOR AS A DETECTOR OF LOST MOTION.

By Robert Grimshaw, M. E.

[Read by title at the Stated Meeting of the Franklin Institute, September 19, 1883.]

The improved steam engine indicators of the present day, while the legitimate successors of the original and long secret invention of James Watt, in the matter of merely showing the performances in the cylinder and valve-chest, and measuring horse-power, are gradually getting a wider application; and it is to one of their new applications, recently discovered, and not, to my knowledge, heretofore made public, that I desire to call your attention for a few moments.

A very intelligent engineer, Mr. Gilman W. Brown, of Boston, had put in his hands for remedy a most pronounced case of pounding in a high-speed engine. This machine thumped at high speeds and at slow speeds; at high pressures and at low pressures; at early and late cut-offs, and under apparently all imaginable conditions of lead and compression. Wherever it was attempted to locate the thump, it appeared somewhere else; or at least was not where suspected.

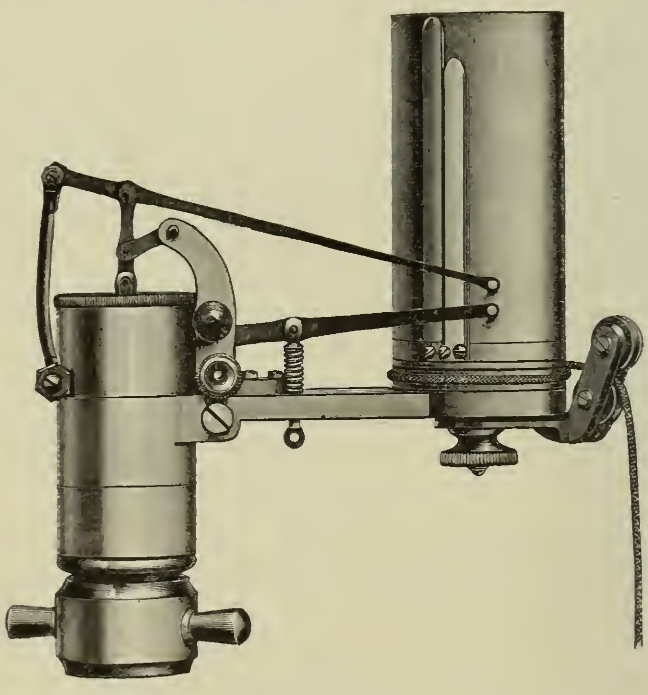
There evidently was only one way to find out where that thump was:—to make it record itself—something which had never before been done, but which was now to be effected.

If the time, and the position in the stroke, at which the thump came in, could in some way be graphically recorded, the problem would be a long way towards solution.

Now, if an indicator can pick out the existence, and locate the time, of lost motion in a valve, why not in that of a crank-pin, or a cross-head pin, or a main bearing?

It is evident that whatever trace the tell-tale instrument should make of lost motion, outside of the valves, should not interfere with its record of the valve functions; and the natural deduction was that there must be another trace, necessitating another marking-point, in no wise connected with the indicator-piston, nor influenced by the steam-pressure.

To effect this, there was added to a "Crosby-Brown" indicator a second multiplying-lever, having a vertical motion only, and bearing a pencil making a trace underneath, and parallel, to the atmospheric and vacuum lines of the usual "diagram." This lever was pivoted to a little standard on the connecting-piece of the instrument, and the pencil position was adjustable in height by a spring and screw, the latter formed on a light rod passing through the connecting-piece. Vertical motion of this rod caused the pencil to vibrate vertically. If the rod was kept at a constant height, the pencil would trace a horizontal line partly around the paper cylinder; but any pull on the rod would make a jog in the tracing.



The main bearing being slacked up, a vertical metal lever was pivoted to the bed-plate, so as to bear against the far side of the main-shaft (assumed to be truly cylindrical, and tested for this purpose, beforehand). The upper end of this lever was connected by a wire, or inelastic cord, passing around a guide-pulley, to the lower end of the vertical rod on the lost-motion lever of the indicator, and all slack taken up, and held out by the spring on the vertical rod.

It is evident that if the main shaft has any horizontal movement, it will cause horizontal vibration of the free end of the lever bearing against it, and thus tighten or slacken the cord and produce a vertical movement of the lost motion lever on the indicator. This will cause a jog, either below or above, in the supplementary horizontal line representing the crosshead path, and will indicate, beyond all question, where the lost motion commences, how long it lasts, in which direction it is from the normal, and when and where it stops.

By the aid of this rig, its inventor effectually cured the hitherto incorrigible engine.

New York, September 8, 1883.

THE WATER SUPPLY OF CITIES IN ANCIENT TIMES.

By Walter Atlee, C. E.

It would seem to be particularly interesting at the present time to give some account from ancient authors of the manner in which the famous water supplies of Rome and other cities, celebrated in antiquity, were conducted.

Ever since men have increased in numbers, and have dwelled together for a more or less time in one locality, great attention has always been given to obtain a permanent and abundant supply of pure water.

Among pagan nations water was regarded with such reverence that it was customary to give names to fountains and springs, and to place them under the protection of the gods.

The ancient Egyptian priests, in order to show that all things could subsist only by the virtue of this element, carried solemnly, with religious respect, into the temple where their god was supposed to reside, an ornamental vase filled with water, and there prostrating themselves on the earth, with their hands raised, gave thanks to the divine goodness for his admirable inventions.*

In ancient Rome was celebrated annually on the III Ides of October (October 13), the feast of the fountains, under the name of Fontanalia. During the half day which the celebration lasted, the fountains and wells were crowned with flowers, and wreaths were thrown into the springs of running water.

The Germans, even a long time after the introduction of Christianity, continued in certain districts to make pilgrimages to several fountains consecrated to pagan gods.

If history furnishes but few and scattered accounts of the art of furnishing cities with water, we find in national traditions and monuments the proof that the science of hydraulics dates back to the most remote antiquity.

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* Vitruvius lib. 8, preface.

We know that Persia possesses canals for irrigation, the origin of which is lost in the "night of ages," and which nevertheless continue at the present day to perform their functions.

In the province of Anachosia ruins of canals attest the former existence of a vast system of irrigation.

At Memphis is the ancient aqueduct of Sestorius.

Semiramis constructed at Babylon her celebrated aqueduct.

The city of Jerusalem was supplied by water through an aqueduct built by Solomon. The whole plain at Persepolis was at one time traversed by hydraulic constructions, the ruins of which show that conduits made of stone and pottery large enough for a man to enter were supported by masonry above the level of the plain.

The traveler Tavernier went from Aleppo to Ispahan by the route of the Great Desert, and arrived at a large abandoned palace before the entrance to which was a reservoir communicating with a canal, then completely dry, the bottom and the roof, which latter was level with the surface of the ground, were constructed of bricks. The Arabs who accompanied Tavernier said that the canal had served to bring water from the Euphrates, which was at least fifty miles distant.

Joseph's well, at Cairo, although of more recent date, is probably the most wonderful subterraneous work ever performed by man. A brief and clear account of this structure is given by Ewbank.

There is also at Cairo a long aqueduct, built of masonry, which for its greater length is supported by arcades, constructed about the same time as Joseph's well.

The engineering skill of the ancient Greek is shown by the celebrated aqueduct constructed by Eupalinos, of Megara, which Herodotus mentions as one of the wonders of the Island of Samos;* this exceedingly interesting object for the archæologist pierces, for two and a half miles, the heart of the mountain back of the town, whose inhabitants it supplied with water from a perennial spring.

From an article in Macmillan's Magazine for August, 1883, we learn that a priest named Cyril, from the monastery of the Holy Trinity, last spring, while plowing, discovered the long lost southern entrance of this aqueduct. At a cost of 20,000 francs the Samiotas have now almost completed the restoration of the ancient channel with the view of again utilizing it, in supplying the town with water. Amongst the ruins of the aqueducts of ancient Greece that of Patara, in Lycia, is most interesting. It consists of a syphon constructed with cut stones supported by an arch in cyclopean masonry, dating to the most remote antiquity.

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* Herod. lib. 3, ch. lx.

But it is, above all, the Romans who particularly attract our attention by their hydraulic constructions, the magnificence and daring of which surpass those of all other nations.

Rome is the only city of antiquity of which we have any detailed account of the administration of the collection, conveyance and distribution of water.

The Romans, enabled by their enormous wealth to gratify their love of display and indulgence in luxurious habits, constructed those monuments of hydraulic engineering which Frontinus speaks of as being " worthy of the greatest care, since they are a principal testimony of the grandeur of the Roman empire," " rem enixiore cura dignam, cum magnitudinis romani imperii id præcipuum sit indicium."*

At the fall of the Republic, 45 B. C., Rome, according to Frontinus, possessed four aqueducts. The Appia, constructed in 442 Roman era, by the emperor Appius Claudius. The Anio Vetus, built in the year 481 Roman era; the Marcia and the Tepula.

The emperors Augustus, Caligula, Claudius and Trajan constructed at Rome other aqueducts, more magnificent than those of their predecessors, so that at the time of Frontinus (850 Roman era, or 97 B. C.) there existed nine aqueducts, namely, (in addition to the four already mentioned,) the Julia, the Virgo, the Alsetina and the Claudia.

The aggregate length of these most useful monuments was $267\frac{3}{10}$ miles. For $228\frac{3}{10}$ miles the channels were entirely underground, and for 39 miles above the surface of the ground, of the latter $34\frac{7}{10}$ miles were supported by arcades or ranges of arches.

The following brief account of the character and construction of the Roman aqueducts is mainly taken from " Les aqueducts Romains " by M. Belgrand.

The first aqueducts, the Appia, the Anio Vetus and above all the Marcia, bear the robust character of the masonry of the earliest ages, they were constructed of cut stone, very simply dressed, but adjusted with precision, so that we see that the engineer relied more upon the resistance of the stone than that of the mortar.

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* Frontinus, ch. cxix.

The Tepula aqueduct was built in 627 Roman era, or but nineteen years after the completion of the Marcia, nevertheless the mode of construction was different; during that time the Romans had become masons and understood that with good mortar and rough material, they could produce a construction as solid as with cut stone and at a much less cost.

The same mode of construction was employed in the other aqueducts, with the addition of the introduction of bricks, except in that of the Anio Novus, which, when it approached the city, surmounting the Claudia took a character of magnificence, the rough materials being abandoned and cut stone entirely employed.

The cross sections of the channels through which the water ran varied from 3 to 8 feet in height, by 2½ to 5 feet in breadth, the bottom was horizontal and the sides perpendicular to it; the shape of the top or covering varied even in the same aqueduct, it being sometimes arched and at others peaked, and sometimes horizontal or parallel with the bottom.

The necessity of maintaining the aqueducts at a gradual inclination from their sources in the mountains to the place of delivery of the water in the city, forced the engineers, when they came to the numerous abrupt and deep ravines of the Apennines, to build sub-structures consisting of one or more arches; and often of several ranges of superposed arches where it was necessary to attain the required elevation.

In traversing the valleys it was often necessary to construct those arcades, the ruins of which are at the present day the wonder of all those who behold them, and no traveler considers that he has seen all the curiosities of Rome till he has visited at least the Plain Roma Vecchia, which is so remarkable for the ruins of the ancient aqueducts, especially for that of the Claudia surmounted by the Anio Novus, distinguishable by a high and exceedingly long line of arcades, extending beyond the power of vision.

The first four aqueducts constructed crossed the valley Degli Archi in the Apennines on magnificent arcades, the ruins of which are classed among the most curious of Italy.

There is an aqueduct bridge of the Anio Vetus composed of thirty-five arches, forming two ranges of arcades superposed, which travers the valley now called St. John.

The aqueducts Anio Vetus and Marcia descended by regular grades the mountains Spaccato and St. Angelo, and crossed the first ravine of the Apennines on the same bridge, also composed of two ranges of arcades. This ruin, now called St. Anthony's bridge, is considered very beautiful.

The want, more and more pronounced, of water at a higher elevation obliged the Roman engineers, especially in crossing the plain near Rome, to support the aqueducts on higher and higher arcades. Thus the elevation of the Marcia water being insufficient, the Tepula, nineteen years afterwards, was constructed at a greater altitude. Ninety-two years later the Julia was built, at a still greater elevation, and eighty-four years after the completion of the Julia, the water still being too low, the high arcades of the Claudia were superposed on those of the Anio Novus, crossing the plain near Rome at an elevation of one hundred and nine feet above its surface.

Not only at the Eternal City, but wherever the Romans extended their conquests and established cities, they built those gigantic hydraulic monuments which prove to posterity the great importance they attached to the enjoyment of an abundant supply of water.

Amongst the ruins of these beautiful constructions with which Gaul was dotted after the Roman conquest, there still remain several aqueducts in active service. That called at present the "pont du Gard" supplies the town of Nimes with water from the two springs, Aire and Airan. This aqueduct consists of a stone channel, 291 yards long, supported by three ranges of arches superposed and attaining an elevation of 160 feet.

At Metz the Moselle river is crossed by the aqueduct of Segovia, which brings water from the valley of Gorge, 23 miles distant.

A part of the water of Paris is still supplied by the Roman aqueduct passing near Arceuil.

Nothing gives a higher idea of the ancient splendor of the city of Lyons (Lugdunum) under the Roman emperors than the remains of the ancient aqueducts erected under Augustus, Tiberius, and Claudius to furnish the city with water.

But no country shared so well in grand Roman hydraulic monuments as Spain, where aqueducts and baths, or their remains, are found in most of the large towns. Those of Merida, Toledo and Tarragona are worthy of being compared to those of Rome itself. The aqueduct of Segovia, in spite of the ravages of time, of civil and political disturbances, has never ceased to fulfil its ancient purpose, and to-day still furnishes the city with all the water necessary for its consumption. This aqueduct, nineteen miles in length, is justly celebrated for its admirable arcades, 700 yards long, composed of 109 arches supporting the channel at an elevation of 107½ feet above the valley.

Constantinople, the Rome of the East, was also justly celebrated for its water-supply brought to the city by the renowned aqueducts of the emperors Valens and Justinian.

The magnificent Carthagenian aqueduct carried its supply of water through mountains and over valleys for seventy miles; near the town of Undena it was supported by an arcade of more than a thousand arches, the elevation of the channel exceeding in some cases 100 feet above the surface of the ground.

Rome was long celebrated for the purity and freshness of its water. The Romans knew that spring and well waters alone were suitable for drinking and culinary purposes; that river water should be reserved for watering and washing streets and parks, to supply the needs of industry, ornamental fountains, and the celebrated amphitheatres where they were so fond of witnessing the famous naval sham-combats.

They knew that water to be good should be limpid, of a moderate temperature in winter and summer, inodorous and above all of an agreeable taste. Vitruvius* tell us "that we can, by means of several observations, know the quantity of the water of a district. If it flows along the surface of the ground, it is necessary before enclosing it in conduits to consider the physical condition of the inhabitants, if they are robust and have good color, and are not subject to diseases of the limbs or runnings from the eyes, the water may be considered fit for use. To test the quality of the water of a newly discovered spring it is necessary to throw several drops of it on Corinthian brass; and if it leaves no spots it is a sign that the water is excellent. It will be the same if, after having been evaporated, no mud or muddy deposit remains, and if vegetables boiled in this water cook quickly. Finally, we shall know that the water is light and very healthy if, being clear and beautiful in its source, it deposits in the places by which it passes neither moss, rushes, nor other impurities."

Until the 442d year after the foundation of Rome, or 310 years before the Christian Era, the inhabitants of the Eternal City contented themselves with water from the Tiber and from the most agreeable springs of the locality. They had at the foot of Mount Cœlis the fountain of Mercury; on the Palatin Hill the fountain of Saturn; from the famous grotto of the Louvre still flows the Lupercale water; in the same neighborhood is also the spring of Castor and Pollux.*

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* Lib. 8, ch. iv.

A. Cassio speaks also of four other springs—those of Lantulus, of Picus and Faune, of Cybele and of the nymph Egeria. For the waters of these springs and fountains the Romans had a profound veneration.

When Rome became powerful and rich she knew of no better manner in which to employ the plunder and slaves procured by her victorious arms than by constructing monuments as remarkable for their daring in architectural design as for their utility. She therefore constructed her famous aqueducts and thus availed herself of the remarkable advantage of being situated on seven hills at a distance not too great from the Apennine mountains which contain at a much greater altitude innumerable springs and lakes of pure water, by bringing for the health, comfort and luxury of her inhabitants this pure liquid to the summit of these hills by means of gravity through aqueducts, and thence distributing it throughout the city. The sources of the water of the Marcia and of the Claudian aqueducts are each 1030½ feet above their respective locations of delivery.

The water of the Marcian spring on account of its remarkable purity and agreeable taste was reserved by an edict of the Emperor Nerva for drinking.

Frontinus considered it a sort of profanation to have used this beautiful water for ordinary purposes.

The Romans having decided upon the springs or lakes from which they wished to augment the supply of water for the Eternal City, and having assured themselves that the sources were situated at an elevation sufficiently greater than that of the locality where they wished to deliver the water, first collected the water into reservoirs from which it ran through a channel built of masonry on a regular incline so that the water might run by the action of gravity to the storage reservoirs from which it was distributed, sometimes the water was made to pass through intermediate reservoirs for the purpose of purification by permitting the water to remain at rest long enough for the mud and other impurities carried along by the force of the motion of the water, to fall and be deposited on the bottom of the reservoir.

Near the seventh mile stone from Rome, on the Latin road, six of the aqueducts emptied their supply of water into covered wells or reservoirs, from which the water continued its journey through aqueducts to the walls of the city, where it was received in "castelli,"* or water-towers, which were structures built of masonry enclosing a basin, near which were three reservoirs fed from the basin by three pipes which distributed the water equally.

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* Belgrand, Idem p. 17.

These reservoirs were so placed that the centre one would receive in times of abundance the surplus water of the other two. From this reservoir of the centre the water was distributed to the public fountains and amphitheatres. The public baths were supplied with water from one of the other reservoirs. Private establishments obtained from the third reservoir their supply of water.

The water towers of the Julia and Claudia aqueducts were very important monuments, the ruins of which still remain.

Besides the public water towers there were private and special towers, which in the time of Frontinus numbered in the city of Rome 247. The public towers received the water directly from the aqueduct or from a branch of it, from which a portion of the water ran continuously through leaden pipes into the public fountains of the vicinity from which most of the people obtained the water necessary for domestic purposes.

The inhabitants of those portions of the city more distant from the public water towers into which the aqueducts emptied, were supplied with water from special towers to which the water was brought by conduits from the public towers. Private dwellings were supplied directly from the nearest water tower, or when situated at a too remote distance, the wealthy inhabitants were accustomed to build private towers for their special use. These towers and the dwellings were each supplied by their special conduits in lead or pottery; each conduit receiving its amount of water from an opening in the water tower, to which was attached horizontally a bronze pipe or gauge of a diameter and length, regulated by law, in proportion to the amount of water to be supplied; this diameter was maintained for a distance of twelve digits or nine inches, for if the opening alone were of the required diameter and a larger pipe were attached, immediately the pressure on the water would cause it to fill the larger pipe and thus supply a greater amount of water than that granted by the concession. This bronze pipe was therefore a sort of meter, which, if properly placed and the water of the reservoir maintained at a certain elevation, would indicate the amount of water supplied. From this gauge or meter the water was conducted through conduits in lead or pottery under the paving of the streets to the dwelling of the consumer, where it ran continuously, day and night, from a fountain, into a sort of basin or reservoir called the "impluvium," which occupied the centre of the interior court or "cavaedium," forming a part of the "atrium" or vestibule characteristic of the dwellings of the wealthy Romans.

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* Vitruvius, lib. 8, ch. vi.

This arrangement can be seen in all the larger houses at Pompeii; the smaller houses were not supplied with water, the artizan dwelled in his shop and procured the necessary supply from the public fountain.

The houses were thus supplied by water through special conduits directly from the reservoir, the water ran continuously in the court of the dwelling, and not through a large conduit, distributing the water to all the houses near which it passed, nor was the water distributed throughout the dwellings as is customary at the present day.

This mode of distribution rendered the expense of a private supply of water very great, for in addition to his portion of the expense of the maintenance of the tower of the district, the proprietor was obliged to bear the expense of laying the pipe, repaving the street, and maintaining in repair this conduit which was often necessarily of great length.

Through this custom of permitting the water to run continuously, much the greater quantity distributed for public and private service ran to waste.

The Emperor Nerva ordered this surplus water to be so used as to continuously flush the sewers and wash the streets; through some of the latter it ran continuously, a system so inconvenient that it would not be tolerated at the present day. Indeed, it would seem that the Eternal City would have become uninhabitable but for this abundant supply of water.

Frontinus considered this employment of the surplus water as one of the benefits of the reign of the Emperor Nerva, he says, "that the super-abundant water was no longer useless, the sanitary condition of the city was already changed, the air purer, the causes of that pernicious air, of that infamous air of the city of our forefathers were destroyed."

Vitruvius has left us a detailed account of the manner in which very long valleys could be crossed by means of the syphon; but the

Romans were only able to employ the syphon where but a small quantity of water was required, for they had not made sufficient advance in the working of metals to be able to economically employ any but lead pipes, and these were of such an inferior quality that the force of the water would often burst the pipes, especially in the curves.

According to the very careful calculations of M. Belgrand,* the water entering the nine aqueducts existing at the ascension of the Emperor Nerva, amounted to 252 million gallons each twenty-four hours, corresponding to about 252 gallons for each inhabitant of the city; about 27 million gallons of water were extracted inside and as much outside the city, in the name of Cæsar for the use of Imperial property, but much the larger quantity estimated at 83⅓ million gallons was extracted by fraud.

Frontinus tells us that he found fields irrigated, taverns and drinking places supplied by water, the proprietors having fraudulently turned the public water from the aqueducts.

Frontinus applied himself so assiduously to prevent these fraudulent extractions of water and with such success that he says, "the quantity of water recovered could be regarded as a new acquisition."† According to M. Belgrand, the amount of water was thus increased to 132 gallons for each person every twenty-four hours.

The water conceded for the public service in the time of Frontinus supplied 19 fields, 39 amphitheatres, 591 fountains and lakes, and 94 public establishments.

In the beginning the distribution of water for the city of Rome was very simple; all the water ran from the reservoirs into the public fountains, individuals could only use the water which fell from the inlet of the fountain into the basin. This water, after it had run from the basin of the fountain, was conceded to the public baths and for the use of fullers, they having obtained the right in consideration of paying an annual water-rent to the public treasurer.

Later, the water which escaped from the aqueducts through leaks was sometimes granted by concession to individuals. Frontinus‡ very justly remarks that these concessions favored frauds of many kinds, and were consequently very rarely granted by the emperors.

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* Les aqueducts Romains, p. 98 and 105.

† Frontinus, ch. lxxvii.

‡ Id. chps. cx and cxl.

The administration of the water-supply was confided sometimes to those holding the office of "censor," and at other times to those holding the office of "edile." The maintenance of the aqueducts was ordinarily contracted for, and the contractor was obliged to keep a certain number of slaves employed on the aqueducts. The names of these workmen, their duties, and the location in which they were to be employed were inscribed on the public bulletins. Their work was subject to the approval of the official in charge of the administration of the water-supply. The administrator regulated all the details of the service. On the days of the great performances in the amphitheatres no one was permitted to use even the most necessary water without a special order from the administrator.

There were very severe laws against those fraudently turning the water from the aqueducts; fields thus irrigated were confiscated, and the public contractors who permitted the frauds were arrested.

Those convicted of wilfully impairing the quality of the water were fined 10,000 sesterces ($280). To insure the execution of this two citizens in each district were chosen from among the inhabitants or property-holders in the neighborhood to oversee the public water.

These laws which punished so severely offences, which by public opinion were not considered dishonorable, were consequently very inefficacious, and must have been very little better than a dead-letter, for it would have required but little attention and care to have prevented the aqueducts from being opened and the water turned away, and to have prevented the planting of trees and the building of houses over the underground portions of the channels. Nevertheless, the most scandalous abuses are noted by Frontinus as being customary.

In the year of Rome 719 the supply of water became insufficient for the wants of the inhabitants. M. Agrippa, son-in-law of the Emperor Augustus, then holding the office of edile, completely restored the then existing aqueducts and constructed at his own expense two others, the Julia in the year 719, Roman era, and the Virgo thirteen years later. He reorganized and introduced admirable order into the administration of the water-supply of Rome, opened a regular account of the receipts and of the distribution of water for public and private concessions; he made laws to insure the preservation of the aqueducts and the maintenance of an abundant supply of water. He made out in detail the amount of water to be distributed to each water-tower and from which aqueducts the supplies should be drawn, the quantity to be employed for public use and the amount to be distributed to individuals. He employed and maintained at his own expense a *family* of slaves, consisting of 240 men for the preservation of the water-supply, the care of the aqueducts, water-towers, and reservoirs.

Agrippa, having thus rendered his term of office when edile celebrated for the care he took to increase the water-supply by the restoration of the ancient aqueducts and by constructing two new ones, and above all, by the complete reorganization of the administration, so as to insure the preservation of these edifices and the abundant supply of water, was the first to be entrusted with the superintendence of the water-supply for life.

Those charged with the administration of the water-supply of ancient Rome were chosen from amongst the most illustrious citizens. Frontinus gives the names of his seventeen predecessors, who were all great personages or belonging to illustrious families; men distinguished for military or civic virtues, successful commanders, ex-consuls, and other dignitaries, were among those considered worthy and capable of being entrusted with the superintendence of the distribution of water and the preservation of the aqueducts. They alone were held to possess the talents, experience, and integrity necessary to properly conduct this most important department of the administration of the Eternal City.

Until the death of Agrippa the administration of the water-supply of Rome had been regulated by special authority, and was subject to no general law. The Emperor Augustus confirmed by an edict the permits recorded in the registers kept by the order of Agrippa, and having inherited the slaves employed for the preservation of the aqueducts, he donated them to the State. He established the gauges by which the quantity of water was regulated and limited to 25, the number of openings permissable in each tower. He nominated Messala Corvus to exercise the functions of administrator of the water, and empowered him to make laws regulating the supply. He granted him two assistants, and to them were accorded the same marks of dignity as were given to magistrates. When they exercised their functions outside the walls of the city, they were surrounded by a numerous escort composed of two lectors, three public slaves, an architect for each of them, clerks, messengers, tipstaves and criers equal in number to those accorded to the functionaries who distributed the wheat to the people. When they exercised their functions inside the city the lictors were withdrawn.

We thus see that the dignitary in charge of the maintenance of the water-supply of Rome was empowered to exercise force in performing his duties. It was decreed that during the fourth part of the year they were to attend to the public and private demands relating to the distribution of water, but this order fell into disuse either from the negligence or from the inability of some of the administrators, although the public treasurer continued to pay the tipstaves and other employees, who ought during that time to assist the administrators.

The administrators were especially advised to prevent any distribution to individuals without an order from the prince, so that no one might obtain any public water that had not been granted him, nor any one receive more than was conceded to him.[*]

This law had been so much neglected that Frontinus tells us "that by enforcing it he would be able, with the quantity of water recovered, to establish new fountains, and to supply new permits of the prince, and that it was necessary at all times to prevent fraud, by an active superintendence; in order to do so successfully, the aqueducts outside of the city should be visited from time to time, and also the water towers and public fountains, to enable the administrator to become acquainted with the nature of the concessions and to insure the flowing of the water night and day without interruption."[†]

Frontinus, in his "De Aquae Ductibus Urbis Romæ Commentarius," says, "Everything confided to us by the emperor requires our greatest care, but I feel myself naturally disposed as much by duty as by taste to acquit myself well of the new functions with which the emperor Nerva, a prince as zealous as well-intentioned for the interests of the republic, has just charged me in confiding to me the administration of the water of Rome, both for their use and for their purity and safety; a function which has always been exercised by the first citizens of the State. I thought that the best way was to do in this as I have done in other circumstances, in order to well understand the object of my enterprise, and I do not believe in fact that there is a surer way to be able to judge well of what should be done and what should not be done, nor is there any thing more shameful for an administrator than to act only by the counsels of his agents, which must certainly occur when the chief, from want of experience, is obliged to have recourse to those who should be under his direction, and who, although necessary, ought only to be regarded as the hands and instruments of the administrator. This is why I have followed in this the same method that I pursued in several of my other functions, in arranging in order all the information that I could obtain concerning this object, united in one body in this commentary to serve me as a guide during my administration."

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[*] Frontinus, ch. ciii.

[†] Id. ciii.

Those who wished to have a concession of the public water, had to obtain permission from the prince by a letter, which, if approved, was presented to the administrator of the water supply. The latter placed the affair in the hands of his assistant, who designated to the guardians of the water tower from which the water was to be drawn, the location of the opening to be made and the size of the gauge to be attached in accordance with the quantity of water conceded.

A concession lasted as long as the person or persons lived in the locality for which the water was granted. This right could not be transferred to a purchaser of the locality nor could it be inherited with the property. But the public baths had the perpetual use of the water which had once been accorded to them.

These long concessions were rendered necessary by the expense required to conduct the water to the locality to be supplied, often a long distance from the aqueduct, and requiring the construction of a private water tower or reservoir.

When a concession became vacant through the death or removal of the proprietor, it was publicly announced.

The administrators had been accustomed to stop the distribution of water immediately on the expiration of a concession, and to sell the right to the new proprietors or to others, but the Emperor Augustus ordered thirty days to be granted, so as not to stop too suddenly so necessary a supply and to give time to make the customary demands for the renewal of the concession.

Concessions were afterwards made of the surplus water which ran from the reservoirs and from the leakage of the aqueducts. This last was very seldom permitted by the princes for it was easy to enlarge the fissure so as to supply any quantity of water desired, and this flow aided the rapid destruction of the aqueduct itself.

Frontinus having measured the quantity of water entering the aqueducts, and having ascertained that it greatly exceeded that which was registered as having been employed for public use, or granted by concessions, set to work to find by what negligence or fraud this great quantity was lost to the state and to understand how to prevent it.

He tells us that he found gauges of a diameter larger than was permitted by the concessions, some of which were not marked, which proved the dishonesty of the agent who controlled the placing of the gauges, he having been bribed to furnish more water than was justly due.

In certain water-towers the gauges were of the right size at the opening but instead of maintaining, this diameter for the distance required by law, a larger tube had been attached to the opening, thus furnishing more water than alloted by the concession as already described.

The locations of some of the openings were below that of others, thus on account of the greater pressure upon the lower openings they supplied a proportionately greater quantity of water.

In several towers, pipes were attached to the openings without any gauge, but were so arranged that they could be enlarged or contracted at the will of the guardian.

Another very reprehensible fraud on the part of the guardians was, when a concession changed hands, instead of using the old opening to supply the person obtaining the renewal of the concession, to pierce a new opening and to sell the water from the former for their own interest. Frontinus adds that the suppression of such a fraud should attract the especial attention of the administrator of the water, for it is his duty to take care not only of the water but also of the preservation of the towers for the latter would be very soon ruined if holes could be arbitrarily pierced.

In examining the condition of the different branches of lead pipes placed under the pavements, which circulated thoughout the whole city, they were found to be pierced with holes in many places by an instrument called a "pointer," the water flowing from these holes was sold by the purveyor for his own profit to all those wishing to arrange with him, the water being lead from these openings by private tubes to the dwellings.*

A large quantity of water destined for public use was turned from its legitimate course in this manner as Frontinus † proved by the increased amount received at the outlet of several pipes after the holes had been closed.

The labor required to preserve the aqueducts and to maintain a proper distribution of the water, was performed by the men of two families of slaves.

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* Frontinus, ch. cxiv.

† Id. ch. cxv.

One family* belonged to the public, having been inherited from Agrippa by his father-in-law, the Emperor Augustus, who gave them to the State as already mentioned. This family comprised about 240 men.

The second family, consisting of 460 men, belonged to the family of Cæsar, and was established for this purpose by the Emperor Claudius when he built his aqueducts. These men were classified according to the work they were required to perform; into guardians of the water-towers, inspectors, pavers, pipemakers, and laborers. A certain number of these men were required to live outside the city, in order that they might be able to repair promptly any damage caused by accidents to the aqueducts, for although the damage might be slight at the time of occurrence the force of the running water would very soon increase very materially any crevice in the masonry through which it might escape, and thus not only delay the supply of water to the city, but destroy the foundations of the aqueduct. Some of the guardians were lodged in the water-towers. All the other men dwelt in the vicinity of the water-towers and amphitheatres which were supplied with water, and were expected to continually hold themselves in readiness to aid in abating any damage caused by accident, and when necessity required to aid in directing the supply of water ordinarily running to several districts at once into any special district requiring immediately a more abundant supply.

Frontinus tells us that he found that these men, through the negligence of the overseers, were accustomed to leave the duties required of them for the public good and to work for their own individual profit.

To re-establish and keep order amongst so great a number of men as composed these two families, Frontinus required that the work to be performed on the morrow should be designated the previous evening; he also kept a record of the work performed each day.†

These men were paid by the public treasurer, and this expense was defrayed by the money paid for concessions of water. This amounted, in the time of Frontinus, to 250,000 sesterces‡ annually; this revenue was often taken for other purposes. The Emperor Domitian used it for his own benefit; Nerva caused it to be returned to the public treasury.

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* It will be remembered that *familia, a family*, means properly, *the servants belonging to a common master.*

† Fr., ch. cxxiii.

‡ This amounts to but $8,500 of our money, but the great difference of relative value must be taken into consideration.

The expenses of the supply of water for Imperial properties were paid from the public treasury, as were also those for pipes and all expenses relative to the maintenance of the aqueducts, water-towers, and reservoirs, or public fountains.

The maintenance of the aqueducts was the especial care of the administrator, for they were exposed to many and frequent causes of damage, which it was necessary to foresee and prevent.

Accidents were occasioned by the ravages of age, by exposure to intense cold and heat, by the violence of tempests, through the fault of badly constructed work, and by the dishonesty of the proprietors of the fields adjoining the aqueducts, who fraudulently caused the water to escape from the channels in order to irrigate their land.

Those portions of the aqueducts supported by arcades suffered most from the effects of age and the violence of the mountain storms. Where the arcades crossed the rivers the foundations were much exposed to the violence of the current in times of floods. The channels in masonry along the flanks of the mountains were exposed to landslides and many other causes of accident.

It was necessary to bring to the execution of all work required to prevent these accidents, and the consequent interruption of the supply of water, great activity, and to have the work performed with great care.

The channels underground suffered less, not being exposed to the effects of intense cold or heat. Accidents to the channels could sometimes be repaired, while still maintaining the supply of water, by carrying it across or around the break through a temporary channel made of lead pipes held at the proper elevation.

A frequent obstruction to the passage of the water was the gradual deposit of mud on the bottom and sides of the channel, which formed in time hard and thick incrustations, and which gradually narrowed the channel till the passage of the water was finally entirely prevented. Sometimes the mortar would drop out and permit the water to escape, which would damage the walls of the channel and the masonry supporting it.

Only those repairs that were absolutely necessary were permitted during the heats of summer, so as not to interrupt the distribution of water at the season when its use was the most required. Spring and autumn were recommended for this work, as the season most suitable, when the fresh masonry would not be exposed to the intense cold of winter, which would freeze the mortar before it was "set," nor would it be exposed to the heats of summer, which would absorb the moisture in the mortar and thus prevent it from forming a solid mass with the stones; for intense heat is as injurious as intense cold to fresh mortar. Moreover, there is no work which demands as much skill, precision and care as masonry required to prevent the escape of water; each piece must fit exactly according to the rules which most masons understand and few observe.* By preparing in advance all material required, and working with the greatest celerity, the passage of water was interrupted for the shortest possible period, and by working on but one aqueduct at a time, the city was not deprived of too great a quantity of water at once.

The administrators were empowered by the Senate when repairs were to be made to the aqueducts, to procure earth, clay, stone, sand and wood from the adjoining fields and have them transported across the fields if necessary, the damages having been previously appraised.

Fifteen feet were ordered by the Senate to be reserved on either side of the channels, no buildings nor trees being permitted within that space except where the aqueducts were entirely under ground, when the space was reduced to five feet. This law had fallen into such disuse that proprietors often enclosed this ground within their fields and used it for their own convenience, building and planting upon it as they pleased, and making roads over it, and even going so far as to prevent the employees of the administrator of the water supply from visiting those portions of the aqueducts, and thus these constructions were, from want of proper and timely attention, gradually destroyed. The real and prime cause of the destruction of the aqueducts was the negligence of the administrators entrusted with the care of the preservation of these magnificent testimonials of the civilization of ancient Rome; the workmen appointed to attend to the repairs profiting by the negligence, and following the examples of their masters, neglected their allotted work and attended to private affairs.

Pliny tells us that long before his time the City was deprived of the benefit of the water from the Marcia, the Julia, and Virgo aqueducts that the proprietors of the land adjoining the aqueducts had turned all the water to their own use; nevertheless, the water from these aqueducts continued to figure on the public register as amounting to 2242 quinaires daily, exactly as if it were regularly received and distributed.*

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* Frontinus, ch. cx

It is evident from what has been said in regard to water-supply that modern cities have not advanced beyond ancient Rome; indeed, in regard to abundance, no city has ever yet even contemplated supplying to its inhabitants such a large quantity. There, there was an abundant supply for every purpose; that which was used for drinking purposes was brought from a great distance and its freshness was retained by bringing it through conduits of stone and keeping in covered reservoirs, where it was exposed to the action of the air and at the same time protected from the rays of the sun. Great care was taken to prevent any pollution. As to the abuses in ancient Rome of the public water, it is not the place of the writer, nor his object, to remark upon them, or to make any comparison with those of modern times.

Many of the larger cities of both the old and new world have either recently imitated ancient Rome or are now contemplating so doing, by procuring their supply of water from long distances, from localities removed from all causes of pollution, and bringing it to the inhabitants by means of gravity through aqueducts.

OIL DRESSED BELTING.

By Joseph Sharp.

[Read at the Stated Meeting of the Franklin Institute, September 19, 1883.]

Transmission by belting is the rule, rather than the exception, in American manufactories and shops.

It has the advantages of high shaft speed, wide shaft distance, cheapness, and lightness, and of slipping in case of a clog in the machinery, thus preventing serious loss and accident by breakage.

One thing which sometimes stands in its way is that it is not as sure, under very heavy work, as gears are, and requires for such heavy work very great pressure on bearings, to prevent slipping.†

The very principle of its action demands a certain amount of slipping, say from 2 per cent. as a minimum, to 15 per cent. or 20 per cent. as a common occurrence.

This cuts it out from many applications where regularity and proportion of velocity-ratio are necessary.

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* Pliny, lib. 31, ch. xxv.

† The minimum slippage, with one belt, is 2 per cent.; where there are several belts between the motor and the machine there is proportionately more slip.

Anything which renders it more efficient and regular is worthy the particular attention of all manufacturers and mechanics. It is also desirable to increase the regularity and proportion of velocity-ratio.

There are locations, as in paper-mills, tanneries, etc., where those kinds of belts which are susceptible to hygrometric influences cannot be used.

Among the many materials for belts, used and offered for use, may be enumerated, in about the order of their frequency—

1. Tanned leather.
2. So-called "rubber" or "gum."
3. Canvas.
4. "Fulled" leather.
5. So-called raw-hide.

The first has many advantages in strength and convenience of repair over all others. But as ordinarily prepared it has not the driving power of rubber under the same conditions, as has been proved by the experiments of Cheever, Grimshaw, and others.

It has, too, the demerit of being exceedingly hygrometric, hence unfit for use in damp places, or those varying suddenly and greatly in humidity.

The fact is that the inferior driving power of oak-tanned and hemlock-tanned leather, as compared with rubber, is largely due to their stiffness.

This causes transverse wrinkling of their under surfaces, and for any considerable width and thickness of belt, is most disadvantageous on pulleys of small diameter, as has been most conclusively proved by Mr. R. Grimshaw, member of your Institute. This gentleman presented the results of his tests in this direction, in his paper read before your body, on the "Influence of Pulley Diameter on the Driving of Belts."*

For a long time beltmakers have denied that this was so. But the tests and figures to which I refer leave us no longer a doubt on this subject.

It is better to accept a fact, however unpleasant, and to take action in accordance therewith, than to deny it.

I have the honor to announce that I have discovered, and successfully put into operation, a method of "oil-dressing" leather, which gives results which far exceed oak-tanned leather from the same green hides, in tensile strength and in grip or driving power, and produces a durable and waterproof material suited for use in the most exposed and humid conditions.

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* Jour. Franklin Institute, Vol. lxxxiii, 460. (June, 1882.)

Most oil-dressed leather belts, and imitations thereof, while waterproof enough, have been deficient in pliability and strength, and still more so in driving power.

I take pleasure in submitting to the inspection of the members of the Franklin Institute samples of the "oil-dressed" belting, and in appending hereto extracts from the editorial columns of the *American Journal of Railway Appliances*, of New York, dated July 16th and August 15th and 31st.

I make, however, by the consent of the editor-in-chief, a few corrections that are manifestly only typographical, and add to the tables the horse-powers at the more usual belt-speed of 3,300 feet per minute.

CINCINNATI, *September* 6, 1883.

APPENDIX.

From *American Journal of Railway Appliances*, July 15 :

"The following figures show the grip of a four-inch single oil-dressed leather belt, flesh side driving, 180° arc, on a thirty-six inch turned cast-iron pulley.

"In the first column are given the weight in pounds, hung on one end of the belt, and marked T^2; in the second, the amount hung on the other end to make the belt slip on the pulley (marked T_1). The third column gives the difference between these two, *i. e.*, the net-grip, or driving power, in pounds. Supposing the belt to have this same grip at a velocity of 1,000 lineal feet per minute, the horse-power would be as given in the fourth column."

Weight, lbs. on slack end. (T_2)	Weight on other end, to cause slipping. (T_1)	Difference, or grip in pounds. ($T_1—T_2$.)	Horse-power at 1000 feet lineal speed per minute.	Horse-power at 3300 feet lineal speed per minute.
100	233⅔	133⅔	4·1	13·36
150	323	173	5·24	17·3
175	353⅓	178⅓	5·41	17·83
200	373⅓*	173⅓	5·25*	17·33
211	393⅓	182⅓	5·5	18·2

* Probably slipped easier than expected, by reason of a slippery spot in the belt.

From *American Journal of Railway Appliances*, July 31 :

"The same piece of 4″ single 'oil-dressed' leather belt which was run 'flesh side to' over the 36″ cast-iron pulley, as per the records in No. 1 of this series, was then run 'grain side to' over the same pulley, with the following results :

Weight in lbs. on slack side. (T_2)	Weight required to cause slip. (T_1)	Net grip in pounds. (T_1-T_2)	Horse power at 1000 feet belt speed.	Horse-power at 3300 feet belt speed.
75	206⅔	131⅔	3·99	13·16
100	240	140	4·24	14·
150	273⅓	123⅓	3·73*	12·3
175	323	148	4·48	14·8
190	346⅔	156⅔	4·75	15·66
200	366⅔	166⅔	5·05	16·66
246	420	174	5·27	17·4
250	433⅔	183⅔	5·56	18·36
302	573⅔	271⅔	8·02	27·16

"Noting the 'horse-power at 1,000 feet speed,' increasing the slack tension 100 per cent., from 100 to 200 pounds, appears to increase the net grip or horse-power only $\frac{\cdot 81}{4\cdot 24}$, or not quite 20 per cent.

"It will be noted that the grain side of this new 'oil-dressed' belt drove rather better than the flesh at 100 pounds, slack tension, but at 200 pounds this was reversed. If we can depend on these figures, that means that the hair side has naturally a better driving surface, but that increasing the tension flattens down the roughnesses on the flesh side, and thus produces a better driving surface than the hair side under the same tension."

From *American Journal Railway Appliances*, August 31 :

"The first two articles of this series went to contrast the driving power of the hair and flesh sides of an oil-dressed belt, on a turned cast-iron pulley, under various degrees of tension. The same belt was also tried, 'hair side to,' on a new 36-inch poplar-faced pulley made by Dodge Bros., Mishawaka, Ind. ; and as the driving power of wooden pulleys is as a rule greater than that of those with iron rim, the tests were commenced with a very light tension; only 25 pounds at the slack ends.

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* In this set a greasy place evidently caused slip when 150 lbs. were applied.

"The results were as follows:

Weight in lbs. on slack end. (T^2)	Weight required to cause slip. (T^1)	Net grip in pounds. (T^1—T^2)	Max. horse-power at 1000 feet belt speed per minute.	Max. horse-power at 3300 feet speed.
25	116½	91½	2·76	9·15
50	290½	240½	7·3	24·0
100	760	660·	20·	66·0
125	886⅔	761⅔	23·08	76·1
150	1020.	870·	26·4	87·0
200	1186·7	986·7	29·9	98·6
250	1493·	1243·0	37·66	124·3

"We believe these figures to be unparalleled in the history of belt transmission. Comparing the grip at 100 pounds, slack tension, with that at 200 pounds, we find it increased $\frac{8\cdot99}{20}$ = practically 45 per cent.; but comparing the grip at 100 pounds, slack tension, with that of the same side of the same belt on the turned cast-iron pulley we find them as 20 to 4·24, or practically as 100 to 17, or about 6 to 1 in favor of the poplar pulley. That these extraordinary results were in a measure due to the excellence of the belting, is shown by the records of tests made almost a week before with a 6-inch double oak-tanned belt (hair side to), 180° contact on the same 36 new poplar-faced pulley. We had at that time no 4-inch single oak-tanned belt; but it is not very unfair to the oak-tanned belt to compare the 6-inch double belt at 150 pounds, slack tension, with the 4-inch single at 100 pounds. The results were as follows:

Weight in lbs. on slack side. (T^2)	Weight on taut side to cause slip. (T^1)	Net grip in pounds. (T^1—T^2)	Max. horse-power at 1000 feet per minute.	Max. horse-power at 3300 feet.
100	520⅔	420⅔	12·75	42·0
125	780⅓	655	19·8	65·5
150	833⅓	683⅓	20·7	68·3
175	920*	....	....	....
200	1133⅓	933⅓	28·3	93·3

"Suppose we take two-thirds the drive of the six-inch double belt, and compare with the entire net grip of the four-inch belt. We get, then, as follows:

Tension on slack side (T^2)	⅔ Horse-power of six-inch double oak-tanned.	Horse-power of four-inch single oil-dressed.	Per cent. superiority in favor of oil-dressed.
100	8·5	20·	135
125	13·2	23.08	74
150	13·8	26·4	91
200	18·9	37·66	47

"These figures show such a variation that, lacking further examination and knowledge of the surfaces of the two belts, all that we are justified in saying is that the new single oil-dressed belting has a greater grip than new double oak-tanned; and that the lighter the tension, the greater the superiority of the more pliable single oil-dressed belt."

DISCUSSION.

MR. J. W. NYSTROM remarked that the heading of the paper did not indicate its contents. He looked for a description of oil-dressed belting, and found instead the details of some experiments which indicated a smaller coefficient of friction in the belting used than that found in ordinary leather belting and, therefore, this new belting possessed inferior driving power.

He made detailed comparisons in each case, and showed that only the experiments with the wooden pulley, described in the last table, gave results equal to the average results of ordinary belting.

MR. HUGO BILGRAM:—The statement that "the very principle of its action (*i. e.*, that of belting) demands a certain amount of slipping, say from 2 per cent. as a minimum to 15 per cent. or 20 per cent. as a common occurrence," refers undoubtedly to the legitimate creeping owing to the elasticity of the belt, not to a bodily slipping which may amount up to 100 per cent. To say that the loss owing to creeping amounts to 15 or 20 per cent. is undoubtedly unwarranted. I believe that an amount equal to 2 per cent. is rarely reached in practice.

I wish to say, furthermore, that the experiments are tabulated in such a way as to mislead regarding the capabilities of the belts. The comparison of horse-power is based on the tension of the slack side, while it should be based on that of the tight side, and is, therefore, devoid of practical value in the shape in which it is given.

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* Hook that sustained the weights broke; belt did not slip.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS, ON THE COMPARATIXE MERITS OF THE PRESSURE-GOVERNING GAS METER AND GAS BURNER.

Hall of the Franklin Institute,
Philadelphia, March 26th, 1883.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to which was referred for examination the comparative merits of the pressure-governing gas meter and gas burner, report: In judging of the comparative merits of controlling the pressure of illuminating gas at the service meter and at the burner, the first and essential consideration is the requirement that an absolute, unvarying pressure be maintained throughout the premises to be lighted—premises of 60 feet horizontal extent and 30 feet elevation in common dwellings, to even 300 feet horizontal extent and 80 feet elevation in the large manufacturing establishments. The question is which of the two modes of regulation of gas pressure best secures the desired result.

We will assume, as we believe we are right in doing, that practically perfect appliances have been made in both cases. But to the successful application of the perfect governor meter there is opposed an insuperable obstacle which is not encountered by the governor burner. The fact that fluids meet with a certain definite resistance from friction, this resistance increasing in inverse ratio to the square of the diameter of the tube, and also the fact that elevation increases the pressure of illuminating gas so as to considerably more than overcome the loss by friction, the excess being about one-tenth of an inch in each elevation of 15 feet; these considerations make it impossible to maintain a uniformity of pressure throughout an ordinary manufactory, or even a common dwelling, by regulating the pressure at any central point. Your committee have at hand examples fully sustaining this objection to the governor meter.

While the differences of pressure alluded to, at any considerable horizontal or vertical distances from the meter are admitted by all, some have thought that these differences could be overcome by checks applied either in the burner or in the key. We are fully of opinion that such checks could never be so adjusted as to effectually control the flow of gas, and furnish the maximum degree of light, from a given amount of gas. This amount has been found by many experiments, to be obtained when gas burns at about ·25 of an inch ignition pressure. But it would not do to adjust a meter to give this pressure near the outlet, for at any considerable horizontal distance the light would utterly fail. Given half an inch pressure at meter outlet—and at 100 feet from this point, with the ordinary number of burners supplied at intervening distances from the ordinary run of gas pipe, such as prescribed by Gas Trust regulations, the pressure would probably not exceed one-tenth of an inch at the burner. In this case, to furnish the necessary pressure at a distance, the meter must be adjusted to give the gas an inch, or one and a half inches, pressure at the outlet. This excess of pressure in the immediate vicinity it is proposed to overcome by checks, either in the burner or in the key. If applied in the burner, by using smaller tips, this would, to be sure, check the flow of gas, but not increase the already too great ignition pressure. If the check is in the key it would require an independent adjustment in each burner, according to distance, and whenever only some of the burners were lighted the accuracy of the adjustment would be destroyed, and the regulation would prove a failure. Moreover, without taking into account the cost of the governor meter, which in ordinary houses is almost equal to that of governor burners, this plan would prove nearly if not quite as expensive as the use of reliable governor burners; and the throttle, being a fixed opening, is more likely to become clogged than the variable and continually varying opening of the governor burner.

Neither can this check be applied at any one place for each additional elevation, to govern all the burners on that level; for the low ignition pressure, alone admissible to obtain the best light, would not suffice for distant burners. Here also, therefore, each burner must have its regulator; and here also, if only a part of the burners are in use, the regulation is destroyed.

In favor of meter regulators, it is to be said, that they will act at somewhat lower street pressure than governor burners; but reliable governor burners are produced requiring only ·6 of an inch initial pressure, which is only a slight increase over that required by meter regulators.

The committee is far from holding the opinion that a meter governor is of no benefit. On the contrary, it believes that a reliable governor meter may always be so adjusted as to secure some economy in the use of illuminating gas. But the question before the committee is, which method of gas-governing secures the more perfect economy and illumination.

On the whole, your committee concludes: 1st. That, owing to the friction of the gas in traversing the pipes, and also the comparative buoyancy of illuminating gas, it is impossible to maintain a uniform pressure of gas throughout even a limited establishment by use of a central or meter regulator.

3d. That reliable governor burners, *owing to their situation*, will preserve a uniform and unvarying pressure throughout any premises, however extensive, provided the street pressure is sufficient to supply the requisite amount of gas.

Approved Sept. 5, 1883.

H. R. HEYL, Ch'n Com. Science and Arts.

WM H. WAHL, Secretary.

Bleaching by Electricity.—Dr. Dobbie and M. Hutcheson have obtained important results by examining the action of the electric current on a solution of marine salt. The chloride of sodium is decomposed, as is well known, and if the solution is neutral, some of the chlorine is set free and hypochlorite of soda is produced; if the solution is alkaline, there is a simple production of the hypochlorite; if the solution is acid there is a yield of chlorine and of soda. The inventors have sought to apply this reaction to bleaching and their experiments seem to have been perfectly successful. Without going into details, it may be easily understood that the production of hypochlorite, or of chlorine, in a fabric which is impregnated with a solution of chloride of sodium, simplifies the operation of bleaching and renders it much more efficacious, because it takes place in the very pores of the tissue. The washings and the preparatory leachings may thus be dispensed with. Delahaye anticipated the possibility that the invention may lead to a new process for the direct manufacture of soda.—*L'Electricien*, No. 40. C.

MR. THEODORE D. RAND'S CRITICISM OF VOL. C_4, GEOLOGY OF CHESTER CO , PENNA.

The undersigned has expressed elsewhere his views of the defects of this volume, mainly however, confining himself (as he proposes to do in this instance) to those parts which bear upon his own work.

Mr. Rand has noted numerous and flagrant errors in the editing of that portion derived from Rogers.

Mr. Rand thinks that the map of the present writer "of a scale one inch to two miles, with the coloring in dispute, and one long line which has no geological value whatever, but is merely a temporary expedient" (p. vi.), is not a great advance over that published by Rogers twenty-five years ago. All the gneisses and mica schists south of the South Valley hill are embraced in one color. The trap (pp. 87 and 218) on the north side of the serpentine Easttown is not upon the map." That the map is very far from perfect, its author will readily admit, and yet this style of criticism is not unlike that often heard from those good old gentlemen during the late rebellion, who over their breakfast tables were wont to upbraid the officers of our Union armies for their military short-comings. It is easy to find fault with any geological map, and often with better reason than the above quotation shows. For instance, though it is true that Dr. Frazer's map is of one inch to two miles, Rogers' map, over which it is said to be no great advance, is on a scale of one inch to five miles. In scale the advance is thus sixty per cent. Nobody has disputed the coloring except of the belt which the editor of C_4 states that he introduced contrary to the wish of the author of the map. It is true that all the gneisses and mica schists south of the South Valley hill are embraced in one color, because the task of differentiation would have required a much longer time than was accorded, and this was explained to the Chief Geologist, who decided to publish, with a single color for all pre-Potsdam rocks.* But it is not a fact that Roger's altered primal is a well-defined rock; on the contrary, a more heterogeneous collection of gneisses, mica-schists, hydro-mica schists, chlorites, feldspar-porphyries, clays, and quartz slates than are found in the regions which he colored as altered primal, it would be difficult to collect together from the two hemispheres. The statement that "the trap (pp. 87 and 218) on the north side of the serpentine Easttown is not upon the map" is erroneous.

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* This is what was done in the three counties of Adams, York and Lancaster. In the former two the pink color was devoted respectively to "Azoic" and "Azoic slates etc." In the latter two some attempt was made to separate the chloritic areas from the other eozoic or azoic, but it was not satisfactory in the eastern part of Lancaster; and further to the East in Chester it was as before stated a total failure in the time allowed, as was also the attempt to define the southern boundary of the hydro-mica series of the South Valley Hill. The Chief Geologist asserted in the letter of transmittal of CCC that, "Had the whole corps of the survey combined force on Lancaster County for a year it would not have been overstudied." "In fact, there is work in Lancaster County for a diligent geologist for ten years." What should he say of Chester?

Mr. Rand says, "In papers published in the "Proc. Min. and Geol. Sec., Acad. of Nat. Sci.," 1880–81, pp. 9 and 28, Theodore D. Rand asserted that the serpentine in Radnor and Easttown, instead of outcropping in lines which if prolonged, would meet as mapped by Hall and by Dr. Frazer in the present volume, had an echelon structure the strike being from S. 40° W. to S. 60° W., while a line joining the exposures would be nearly E. and W., etc. . . . A map of outcrops was published with the text. If these outcrops are as stated, the fact is of interest; if they are not, the error should have been corrected."

If one subjects this statement to the same test of textual accuracy which its author imposes upon the subjects of his reviews, it will be found wanting. Mr. Rand gives the observations on which he founds his echelon theory in the first of these papers, with three lines of the theory itself (pp. 10, 11). In the second paper no allusion is made to the serpentine in Radnor and Easttown. To quote his own striking phrase, slightly altered: 'I am quite familiar with his two papers. I have searched for allusions to the Radnor and Easttown serpentines in the second of them without finding such allusions in it; and I believe, therefore, that they do not exist.' This, however, is mere word chopping. It is evident that Mr. Rand did announce a theory as to the position of the serpentines, which would be interesting if well-founded —the more so since it would seem to establish beyond a doubt either that there were a series of parallel faults and throws which had successively forced the western portions of the belt containing the serpentine to the north, or the easterly portion to the south, or that there was a zone of serpentine belts at an oblique angle to their strike. The first of these hypotheses will hardly bear examination, the boundary lines of the oldest formations show no such disjointing in the lines of these deposits as would necessarily result from a series of throws such as are imagined. The second presents an old observation in a new light, and is directly in accord with so much of the views of Mr. Charles Hall, the writer and many others as relate to the metamorphic—perhaps metasomatic—* origin of the serpentines; for nothing could more clearly preclude the idea of separate deposits of a given rock than its occurrence in small isolated patches in different horizons of different groups of other rocks with which, nevertheless, it agrees practically in strike. It is, therefore, with no prejudice against the hypothesis that the writer examined into its foundation.

As stated in Mr. Rand's first paper, in (*Proc. Min. and Geol. Sec., A. N. S.*), the first outcrop of his middle belt of serpentine in Radnor township ± ¼ mile N. E. of Radnor station strikes nearly E. and W., as do the rocks which bound it. The southern edge of black serpentine near Morrell's new house (N. E. of Radnor station) strikes about E. 5° N. The general dip is southwardly, and in following the road from Radnor station one passes obliquely to older strata. The perpendicular thickness of the serpentine from its southern to its northern edge is about 141 feet, while the road crosses the strike at an angle of 40° for a distance of about 660 feet.

The complexion of the rocks of this belt is very variable, and the dips across it vary from S. to S. 5° E–65° on the southern edge to S. 10° to 15° E–75° to 85° on the northern edge. It is doubtful if this change of dip has structural significance, but if so it implies a sharp anticlinal here. At a point about 106 feet perpendicularly across the strike is a schist which, while justifying the appellation of talc schist, resembles in its habit that which it in all probability originally was, viz.: a nacreous, perhaps chloritic-nacreous schist. At about 200 feet perpendicularly across the strike occurs a very much decomposed rock containing, besides its talc and chrysotile, quartz, and some little hornblende fragments. A quarry in serpentine near Mr. Morrell's house dips N. 20° W–78°.

The boundary of the serpentine across a small branch of Gulf Creek is a heavy bedded hornblendic gneiss dipping N. 15° W.–87°.

This illustrates the great variations in composition and posture of these serpentinous layers, and also their proximate agreement in this latter particular with the neighboring strata.

Passing by the second ("inconspicuous") deposit to the west we come to a finely exposed quarry on a hill but a couple of hundred feet from Mr. Rand's house.

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* Dr. T. Sterry Hunt has invented, and Principal Dawson, in his recent address before the meeting of the A. A. A. S., at Minneapolis, has employed a new word—"metasomatosis," to replace the old and well-established word, "metasomatism." The advantage of the substitution may be doubted.

Here the northwesterly portion of the deposit dips S. 20° E.–54° though the planes taken for bedding are very much waved and contorted. The southeastern part of the exposure appears to dip N. 30° E–85. The region of the quarry where these diverse planes seem nearly to join is marked by doubtful indications of structure. If there be any foundation for these observations, this would appear to be a synclinal of canoe shape viewed here close to its S. W. end. The thickness of rock dipping S. 10° E appears to be greater than that dipping N 30° E. [A specimen of a lenticular mass (possibly pseudomorph) of green in white serpentine was found here, the interior of the former being transformed into chrysotile.]

These observations seem to show how a continuous structure connecting the detached outcrops might be compatible with a difference of strike from that of the country rock.

Of minor outcrops in Easttown, one, he says, "with a strike of S. 40° W. dips about 75° or 80° S." (sic.)

Passing by the fifth, of which he says the strike is indistinct, and coming to the sixth, "S. W. of (old) Eagle station," thick beds of serpentine are visible, very much waved, dipping E. 30° S.–55° to 60°.

The strike seems to average throughout the quarry ± N. 30° E. There is no indication of either anticlinal or synclinal here, but the rock is talcose schist with a strong resemblance to chloritic character.

The ninth is about a mile south of Berwyn station, near John Ivister's house. The signs of this outcrop are wanting on the road but the opening is seen in a field about 100 feet east of it, and just north of certain indications of trap which can be seen there.

The schistose character of the deposit is indubitable. There are three or four bands of well defined schists bounding the serpentine on the north and on the south and occurring in several lines between these two.

The average dip of the talc schist and serpentine from a number of observations is E. 40° S.–88°. About ten feet north of the excavation a very chloritic-looking schist strikes N. 40° E. Here again the general resemblance to the chloritic schists in habit and the waving character of the beds are prominent features.

To sum up, therefore, it seems to be unnecessary to suppose a strike of the serpentine differing from the general strike of the rocks adjacent to it or from the trend of the detached outcrops, provided that the almost universal waving of the outcrops of the schists generally; and provided that a number of lines of serpentine in the serpentine belt be conceded.

The evidence in favor of the alteration of nacrites, and chloritic rocks into these talc schists and serpentine with their accompanying minerals is partly geographical, partly stratigraphical and partly chemical. As to the first, it is undeniable that directly north of the serpentine numbered "9" by Mr. Rand the hydro-mica schists of the south valley come in and extend to the valley. Though they are not found in place near the serpentine, the aspect of the fragments is much like that of the fragments of the schistose boundaries and partings of the Ivister quarry. As to the stratigraphical side of the case the nacrites show the same meandering strike lines, where exposed, that one sees here in the serpentine; and point directly towards the latter from nearly west and east of this outcrop.* Chemically the large amount of magnesia which these beds contain renders their transition easy to accept especially as innumerable cases of such transitions are well known elsewhere.

To Mr. Rand's implied question, therefore, whether the echelon structure be admitted, I am constrained to answer in the negative according to my present light, though I am open to demonstration and shall be pleased to be convinced.

It should be said in conclusion that if time had been accorded it was the writer's intention to finish the geological map of Chester county by an attempt to differentiate the component parts of what is colored as "Eozoic." A large but not nearly large enough amount of information had been collected to this end, but the demand for a completed map with the minimum delay led to the adoption of the plan which assigned a single color to all the pre-Potsdam series.

Philadelphia, Sept. 20, 1883. PERSIFOR FRAZER.

Preservation of Vulcanized Rubber.—W. Hempel, a German chemist, recommends keeping articles of vulcanized rubber in an atmosphere of petroleum. When tubes, stoppers, or other vulcanized articles are hardened, he states that they may be made pliable by exposing them in an atmosphere of carbon bisulphide.—*Les Mondes*. December 30, 1882. C.

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* It must be admitted that if this waving of the outcrop consists in a variation of strike between E. and N. 30° E., there are instances of serpentine with many intermediate strikes and both the above, in the interval between Radnor and the Paoli. If it were not for this fact it would be difficult to account for the occurrence of Serpentine only in those parts of the measures where the latter strike prevailed.

A PLEA FOR PURE SCIENCE.*

By Prof. H. A. Rowland.

[An address delivered before Section B (Physics), American Association for the Advancement of Science. Minneapolis, 1883.]

The question is sometimes asked us as to the time of year we like the best. To my mind, the spring is the most delightful; for nature then recovers from the apathy of winter, and stirs herself to renewed life. The leaves grow, and the buds open, with a suggestion of vigor delightful to behold; and we revel in this ever-renewed life of nature. But this cannot always last. The leaves reach their limit; the buds open to the full, and pass away. Then we begin to ask ourselves whether all this display has been in vain, or whether it has led to a bountiful harvest.

So this magnificent country of ours has rivalled the vigor of spring in its growth. Forests have been levelled, and cities built, and a large and powerful nation has been created on the face of the earth. We are proud of our advancement. We are proud of such cities as this, founded in a day upon a spot over which, but a few years since, the red man hunted the buffalo. But we must remember that this is only the spring of our country. Our glance must not be backward; for however beautiful leaves and blossoms are, and however marvellous their rapid increase, they are but leaves and blossoms after all. Rather should we look forward to discover what will be the outcome of all this, and what the chance of harvest. For if we do this in time, we may discover the worm which threatens the ripe fruit, or the barren spot where the harvest is withering for want of water.

I am required to address the so-called physical section of this association. Fain would I speak pleasant words to you on this subject; fain would I recount to you the progress made in this subject by my countrymen, and their noble efforts to understand the order of the universe. But I go out to gather the grain ripe to the harvest, and I find only tares. Here and then a noble head of grain rises above the weeds; but so few are they, that I find the majority of my countrymen know them not, but think that they have a waving harvest, while it is only one of weeds after all. American science is a thing of the future, and not of the present or past; and the proper course of one in my position is to consider what must be done to create a science of physics in this country, rather than to call telegraphs, electric lights, and such conveniences, by the name of science. I do not wish to underrate the value of all these things: the progress of the world depends on them, and he is to be honored who cultivates them successfully. So also the cook who invents a new and palatable dish for the table benefits the world to a certain degree; yet we do not dignify him by the name of a chemist. And yet it is not an uncommon thing, especially in American newspapers, to have the *applications* of science confounded with pure science; and some obscure American who steals the ideas of some great mind of the past, and enriches himself by the application of the same to domestic uses, is often lauded above the great originator of the idea, who might have worked out hundreds of such applications, had his mind possessed the necessary element of vulgarity. I have often been asked, which was the more important to the world, pure or applied science. To have the applications of a science, the science itself must exist. Should we stop its progress, and attend only to its applications, we should soon degenerate into a people like the Chinese, who have made no progress for generations, because they have been satisfied with the applications of science, and have never sought for reasons in what they have done. The reasons constitute pure science. They have known the application of gunpowder for centuries; and yet the reasons for its peculiar action, if sought in the proper manner, would have developed the science of chemistry, and even of physics, with all their numerous applications. By contenting themselves with the fact that gunpowder will explode, and seeking no farther, they have fallen behind in the progress of the world; and we now regard this oldest and most numerous of nations as only barbarians. And yet our own country is in the same state. But we have done better; for we have taken the science of the Old World, and applied it to all our uses, accepting it like the rain of heaven, without asking whence it came, or even acknowledging the debt of gratitude we owe to the great and unselfish workers who have given it to us. And, like the rain of heaven, this pure science has fallen upon our country, and made it great and rich and strong.

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* In using the word "science," I refer to physical science, as I know nothing of natural science. Probably my remarks will, however, apply to both, but I do not know.

To a civilized nation of the present day, the applications of science are a necessity; and our country has hitherto succeeded in this line, only for the reason that there are certain countries in the world where pure science has been and is cultivated, and where the study of nature is considered a noble pursuit. But such countries are rare, and those who wish to pursue pure science in our own country must be prepared to face public opinion in a manner which requires much moral courage. They must be prepared to be looked down upon by every successful inventor whose shallow mind imagines that the only pursuit of mankind is wealth, and that he who obtains most has best succeeded in this world. Everybody can comprehend a million of money; but how few can comprehend any advance in scientific theory, especially in its more abstruse portions! And this, I believe, is one of the causes of the small number of persons who have ever devoted themselves to work of the higher order in any human pursuit. Man is a gregarious animal, and depends very much, for his happiness, on the sympathy of those around him; and it is rare to find one with the courage to pursue his own ideals in spite of his surroundings. In times past, men were more isolated than at present, and each came in contact with a fewer number of people. Hence that time constitutes the period when the great sculptures, paintings and poems were produced. Each man's mind was comparatively free to follow its own ideals, and the results were the great and unique works of the ancient masters. To-day the railroad and the telegraph, the books and the newspapers, have united each individual man with the rest of the world: instead of his mind being an individual, a thing apart by itself, and unique, it has become so influenced by the outer world, and so dependent upon it, that it has lost its originality to a great extent. The man who in times past would naturally have been in the lowest depths of poverty, mentally and physically, to-day measures tape behind a counter, and with lordly air advises the naturally born genius how he may best bring his outward appearance down to a level with his own. A new idea he never had, but he can at least cover his mental nakedness with ideas imbibed from others. So the genius of the past soon perceives that his higher ideas are too high to be appreciated by the world; his mind is clipped down to the standard form; every natural offshoot upwards is repressed, until the man is no higher than his fellows. Hence the world, through the abundance of its intercourse, is reduced to a level. What was formerly a grand and magnificent landscape, with mountains ascending above the clouds, and depths whose gloom we cannot now appreciate, has become serene and peaceful. The depths have been filled, and the heights levelled, and the wavy harvests and smoky factories cover the landscape.

As far as the average man is concerned, the change is for the better. The average life of man is far pleasanter, and his mental condition better, than before. But we miss the vigor imparted by the mountains. We are tired of mediocrity, the curse of our country. We are tired of seeing our artists reduced to hirelings, and imploring Congress to protect them against foreign competition. We are tired of seeing our countrymen take their science from abroad, and boast that they here convert it into wealth. We are tired of seeing our professors degrading their chairs by the pursuit of applied science instead of pure science; or sitting inactive while the whole world is open to investigation; lingering by the wayside while the problem of the universe remains unsolved. . We wish for something higher and nobler in this country of mediocrity, for a mountain to relieve the landscape of its monotony. We are surrounded with mysteries, and have been created with minds to enjoy and reason to aid in the unfolding of such mysteries. Nature calls to us to study her, and our better feelings urge us in the same direction.

For generations there have been some few students of science who have esteemed the study of nature the most noble of pursuits. Some have been wealthy, and some poor; but they have all had one thing in common—the love of nature and its laws. To these few men the world owes all the progress due to applied science, and yet very few ever received any payment in this world for their labors.

Faraday, the great discoverer of the principle on which all machines for electric lighting, electric railways, and the transmission of power, must rest, died a poor man, although others and the whole world have been enriched by his discoveries. And such must be the fate of the followers in his footsteps for some time to come.

But there will be those in the future who will study nature from pure love, and for them higher prizes than any yet obtained are waiting. We have but yet commenced our pursuit of science, and stand upon the threshold wondering what there is within. We explain the motion of the planet by the law of gravitation; but who will explain how two bodies, millions of miles apart, tend to go toward each other with a certain force?

We now weigh and measure electricity and electric currents with as much ease as ordinary matter, yet have we made any approach to an explanation of the phenomenon of electricity? Light is an undulatory motion, and yet do we know what it is that undulates? Heat is motion, yet do we know what it is that moves? Ordinary matter is a common substance, and yet who shall fathom the mystery of its internal constitution?

There is room for all in the work, and the race has but commenced. The problems are not to be solved in a moment, but need the best work of the best minds, for an indefinite time.

Shall our country be contented to stand by, while other countries lead in the race? Shall we always grovel in the dust, and pick up the crumbs which fall from the rich man's table, consisting ourselves richer than he because we have more crumbs, while we forget that he has the cake, which is the source of all crumbs? Shall we be swine, to whom the corn and husks are of more value than the pearls? If I read aright the signs of the times, I think we shall not always be contented with our inferior position. From looking down we have almost become blind, but may recover. In a new country the necessities of life must be attended to first. The curse of Adam is upon us all, and we must earn our bread.

But it is the mission of applied science to render this easier for the whole world. There is a story which I once read, which will illustrate the true position of applied science in the world. A boy, more fond of reading than of work, was employed, in the early days of the steam-engine, to turn the valve at every stroke. Necessity was the mother of invention in his case: his reading was disturbed by his work, and he soon discovered that he might become free from his work by so tying the valve to some movable portion of the engine, as to make it move its own valve. So I consider that the true pursuit of mankind is intellectual. The scientific study of nature in all its branches, of mathematics, of mankind in its past and present, the pursuit of art, and the cultivation of all that is great and noble in the world—these are the highest occupation of mankind. Commerce, the applications of science, the accumulation of wealth, are necessities which are a curse to those with high ideals, but a blessing to that portion of the world which has neither the ability nor the taste for higher pursuits.

As the applications of science multiply, living becomes easier, the wealth necessary for the purchase of apparatus can better be obtained, and the pursuit of other things besides the necessities of life becomes possible.

But the moral qualities must also be cultivated in proportion to the wealth of the country, before much can be done in pure science. The successful sculptor or painter naturally attains to wealth through the legitimate work of his profession. The novelist, the poet, the musician, all have wealth before them as the end of a successful career. But the scientist and the mathematician have no such incentive to work: they must earn their living by other pursuits, usually teaching, and only devote their surplus time to the true pursuit of their science. And frequently, by the small salary which they receive, by the lack of instrumental and literary facilities by the mental atmosphere in which they exist, and most of all, by their low ideals of life, they are led to devote their surplus time to applied science or to other means of increasing their fortune. How shall we, then, honor the few, the very few, who, in in spite of all difficulties, have kept their eyes fixed on the goal, and have steadily worked for pure science, giving to the world a most precious donation, which has borne fruit in our greater knowledge of the universe and in the applications to our physical life which have enriched thousands and benefitted each one of us? There are also those who have every facility for the pursuit of science, who have an ample salary and every appliance for works, yet who devote themselves to commercial work, to testifying in courts of law, and to any other work to increase their present large income. Such men would be respectable if they gave up the name of professor, and took that of consulting chemists or physicists. And such men are needed in the community. But for a man to occupy the professor's chair in a prominent college, and, by his energy and ability in the commercial applications of his science, stand before the local community in a prominent manner, and become the newspaper exponent of his science, is a disgrace both to him and his college. It is the death-blow to science in that region. Call him by his proper name, and he becomes at once a useful member of the community. Put in his place a man who shall by precept and example cultivate his science, and how different is the result! Young men, looking forward into the world for something to do, see before them this high and noble life, and they see that there is something more honorable than the accumulation of wealth. They are thus led to devote their lives to similar pursuits, and they honor the professor who has drawn them to something higher than they might otherwise have aspired to reach.

I do not wish to be misunderstood in this matter. It is no disgrace to make money by an invention, or otherwise, or to do commercial scientific work under some circumstances. But let pure science be the aim of those in the chairs of professors, and so prominently the aim that there can be no mistake. If our aim in life is wealth, let us honestly engage in commercial pursuits, and compete with others for its possession. But if we choose a life which we consider higher, let us live up to it, taking wealth or poverty as it may chance to come to us, but letting neither turn us aside from our pursuit.

The work or teaching may absorb the energies of many; and, indeed, this is the excuse given by most for not doing any scientific work. But there is an old saying, that where there is a will there is a way. Few professors do as much teaching or lecturing as the German professors, who are also noted for their elaborate papers in the scientific journals. I myself have been burdened down with work, and know what it is; and yet I here assert that all *can* find time for scientific research if they desire it. But here again, that curse of our country, mediocrity, is upon us. Our colleges and universities seldom call for first-class men of reputation, and I have even heard the trustee of a well-known college assert that no professor should engage in research because of the time wasted! I was glad to see, soon after, by the call of a prominent scientist to that college, that the majority of the trustees did not agree with him.

That teaching is important, goes without saying. A successful teacher is to be respected; but if he does not lead his scholars to that which is the highest, is he not blameworthy? We are, then, to look to the colleges and universities of the land for most of the work in pure science which is done. Let us therefore examine these latter, and see what the prospect is.

One, whom perhaps we may here style a practical follower of Ruskin, has stated that while in this country he was variously designated by the title of captain, colonel, and professor. The story may or may not be true, but we all know enough of the customs of our countrymen not to dispute it on general principles. All men are born equal: some men are captains, colonels, and professors, and therefore all men are such. The logic is conclusive; and the same kind of logic seems to have been applied to our schools, colleges, and universities. I have before me the report of the commissioner of education for 1880. According to that report, there were 389,* or say, in round numbers,

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* 364 reported on, and 25 not reported.

400 institutions, calling themselves colleges or universities, in our country! We may well exclaim that ours is a great country, having more than the whole world beside. The fact is sufficient. The whole earth would hardly support such a number of first-class institutions. The curse of mediocrity must be upon them, to swarm in such numbers. They must be a cloud of mosquitoes, instead of eagles as they profess. And this becomes evident on further analysis. About one-third aspire to the name of university; and I note one called by that name which has two professors and 18 students, and another having three teachers and 12 students! And these instances are not unique, for the number of small institutions and schools which call themselves universities is very great. It is difficult to decide from the statistics alone the exact standing of these institutions. The extremes are easy to manage. Who can doubt that an institution with over 800 students, and a faculty of 70, is of a higher grade than those above cited having 10 or 20 students and two or three in the faculty? Yet this is not always true; for I note one institution with over 500 students which is known to me personally as of the grade of a high school. The statistics are more or less defective, and it would much weaken the force of my remarks if I went too much into detail. I append the following tables, however, of 330 so-called colleges and universities:

218	had from	0 to 100	students.
88	" "	100 " 200	"
12	" "	200 " 300	"
6	" "	300 " 500	"
6	over	500	

Of 322 so-called colleges and universities:

206	had	0 to 10	in the faculty.
99	"	10 " 20	" "
17	"	20 or over	" "

If the statistics were forthcoming—and possibly they may exist—we might also get an idea of the standing of these institutions and their approach to the true university idea, by the average age of the scholars. Possibly also the ratio of number of scholars to teachers might be of some help. All these methods give an approximation to the present standing of the institutions. But there is another method of attacking the problem, which is very exact, but it only gives us the *possibilities* of which the institution is capable. I refer to the wealth of the institution. In estimating the wealth, I have not included the value of grounds and buildings, for this is of little importance, either to the present or future standing of the institution. As good work can be done in a hovel as in a palace. I have taken the productive funds of the institution as the basis of estimate. I find:

234 have below $500,000.
8 " between $500,000 and $1,000,000.
8 " over $1,000,000.

There is no fact more firmly established, all over the world, than that the higher education can never be made to pay for itself. Usually the cost to a college, of educating a young man, very much exceeds what he pays for it, and is often three or four times as much. The higher the education, the greater this proportion will be; and a university of the highest class should anticipate only a small accession to its income from the fees of students. Hence the test I have applied must give a true representation of the possibilities in every case. According to the figures, only 16 colleges and universities have $500,000 or over of invested funds, and only one-half of these have $1,000,000 and over. Now, even the latter sum is a very small endowment for a college; and to call any institution a university which has less than $1,000,000, is to render it absurd in the face of the world. And yet more than 100 of our institutions, many of them very respectable colleges, have abused the word "university" in this manner. It is to be hoped that the endowment of the more respectable of these institutions may be increased, as many of them deserve it; and their unfortunate appellation has probably been repented of long since.

But what shall we think of a community that gives the charter of a university to an institution with a total of $20,000 endowment, two so-called professors, and 18 students? or another with three professors, 12 students, and a total of $27,000 endowment, mostly invested in buildings! And yet there are very many similar institutions; there being 16 with three professors or less, and very many indeed with only four or five.

Such facts as these could only exist in a democratic country, where pride is taken in reducing everything to a level. And I may also say that it can only exist in the early days of such a democracy; for an intelligent public will soon perceive that calling a thing by a wrong name does not change its character, and that truth, above all things, should be taught to the youth of the nation.

It may be urged, that all these institutions are doing good work in education; and that many young men are thus taught, who could not afford to go to a true college or university. But I do not object to the education,—though I have no doubt an investigation would disclose equal absurdities here,—for it is aside from my object. But I do object to lowering the ideals of the youth of the country. Let them know that they are attending a school, and not a university; and let them know that above them comes the college, and above that the university. Let them be taught that they are only half educated, and that there are persons in the world by whose side they are but atoms. In other words, let them be taught the truth.

It may be that some small institutions are of high grade, especially those which are new; but who can doubt that more than two-thirds of our institutions calling themselves colleges and universities are unworthy of the name? Each one of these institutions has so-called professors, but it is evident that they can be only of the grade of teachers. Why should they not be so called? The position of teacher is an honored one, but is not made more honorable by the assumption of a false title. Furthermore, the multiplication of the title, and the ease with which it can be obtatned, render it scarcely worth striving for. When the man of energy, ability, and perhaps genius is rewarded by the same title and emoluments as the commonplace man with the modicum of knowledge, who takes to teaching, not because of any aptitude for his work, but possibly because he has not the energy to compete with his fellow-men in business, then I say one of the inducements for first-class men to become professors is gone.

When work and ability are required for the position, and when the professor is expected to keep up with the progress of his subject, and to do all in his power to advance it, and when he is selected for these reasons, then the position will be worth working for, and the successful competitor will be honored accordingly. The chivalric spirit which prompted Faraday to devote his life to the study of nature may actuate a few noble men to give their life to scientific work; but, if we wish to cultivate this highest class of men in science, we must open a career for them worthy of their efforts,

Jenny Lind, with her beautiful voice, would have cultivated it to some extent in her native village; yet who would expect her to travel over the world, and give concerts for nothing? and how would she have been able to do if she had wished? And so the scientific man, whatever his natural talents, must have instruments and a library, and a suitable and respectable salary to live upon, before he is able to exert himself to his full capacity. This is true of advance in all the higher departments of human learning, and yet something more is necessary. It is not those in this country who receive the largest salary, and have positions in the richest colleges, who have advanced their subject the most: men receiving the highest salaries, and occupying the professor's chair, are to-day doing absolutely nothing in pure science, but are striving by the commercial applications of their science to increase their already large salary. Such pursuits, as I have said before, are honorable in their proper place; but the duty of a professor is to advance his science, and to set an example of pure and true devotion to it which shall demonstrate to his students and the world that there is something high and noble worth living for. Money-changers are often respectable men, and yet they were once severely rebuked for carrying on their trade in the court of the temple.

Wealth does not constitute a university, buildings do not: it is the men who constitute its faculty, and the students who learn from them. It is the last and highest step which the mere student takes. He goes forth into the world, and the height to which he rises has been influenced by the ideals which he has consciously or unconsciously imbibed in his university. If the professors under whom he has studied have been high in their profession, and have themselves had high ideals; if they have considered the advance of their particular subject their highest work in life, and are themselves honored for their intellect throughout the world,—the student is drawn toward that which is highest, and ever after in life has high ideals. But if the student is taught by what are sometimes called good teachers, and teachers only, who know little more than the student, and who are often surpassed and even despised by him, no one can doubt the lowered tone of his mind. He finds that by his feeble efforts he can surpass one to whom a university has given its highest honor; and he begins to think that he himself is a born genius, and the incentive to work is gone. He is great by the side of the molehill, and does not know any mountain to compare himself with.

A university should not only have great men in its faculty, but have numerous minor professors and assistants of all kinds, and should encourage the highest work, if for no other reason than to encourage the student to his highest efforts.

But, assuming that the professor has high ideals, wealth such as only a large and high university can command is necessary to allow him the fullest development.

And this is specially so in our science of physics. In the early days of physics and chemistry, many of the fundamental experiments could be performed with the simplest apparatus. And so we often find the names of Wollaston and Faraday mentioned as needing scarcely anything for their researches. Much can even now be done with the simplest apparatus; and nobody, except the utterly incompetent, need stop for want of it. But the fact remains, that one can only be free to investigate in all departments of chemistry and physics, when he not only has a complete laboratory at his command, but a friend to draw on for the expenses of each experiment. That simplest of the departments of physics, namely, astronomy, has now reached such perfection that nobody can expect to do much more in it without a perfectly equipped observatory; and even this would be useless without an income sufficient to employ a corps of assistants to make the observations and computations. But even in this simplest of physical subjects, there is great misunderstanding. Our country has very many excellent observatories: and yet little work is done in comparison, because no provision has been made for maintaining the work of the observatory; and the wealth which, if concentrated, might have made one effective observatory which would prove a benefit to astronomical science, when scattered among a half-dozen, merely furnishes telescopes for the people in the surrounding region to view the moon with. And here I strike the keynote of at least one need of our country, if she would stand well in science; and the following item which I clip from a newspaper will illustrate the matter:

"The eccentric old Canadian, Arunah Huntington, who left $200,000 to be divided among the public schools of Vermont, has done something which will be of little practical value to the schools. Each district will be entitled to the insignificant sum of $10, which will not advance much the cause of education."

Nobody will dispute the folly of such a bequest, or the folly of filling the country with telescopes to look at the moon, and calling them observatories. How much better to concentrate the wealth into a few parcels, and make first-class observatories and institutions with it!

Is it possible that any of our four hundred colleges and universities have love enough of learning to unite with each other and form larger institutions? Is it possible that any have such a love of truth that they are willing to be called by their right name? I fear not; for the spirit of expectation, which is analogous to the spirit of gambling, is strong in the American breast, and each institution which now, except in name, slumbers in obscurity, expects in time to bloom out into full prosperity. Although many of them are under religious influence, where truth is inculcated, and where men are taught to take a low seat at the table in order that they may be honored by being called up higher, and not dishonored by being thrust down lower, yet these institutions have thrust themselves into the highest seats, and cannot probably be dislodged.

But would it not be possible to so change public opinion that no college could be founded with a less endowment than say $1,000,000, or no university with less than three or four times that amount? From the report of the Commissioner of Education, I learn that such a change is taking place; that the tendency towards large institutions is increasing, and that it is principally in the west and southwest that the multiplication of small institutions with big names is to be feared most, and that the east is almost ready for the great coming university.

The total wealth of the four hundred colleges and universities in 1880 was about $40,000,000 in buildings, and $43,000,000 in productive funds. This would be sufficient for one great university of $10,000,000, four of $5,000,000, and twenty-six colleges of $2,000,000 each. But such an idea can of course never be carried out. Government appropriations are out of the question, because no political trickery must be allowed around the ideal institution.

In the year 1880 the private bequests to all schools and colleges amounted to about $5,500,000; and, although there was one bequest of $1,250,000, yet the amount does not appear to be phenomenal. It would thus seem that the total amount was about five million dollars in one year, of which more than half is given to so-called colleges and universities. It would be very difficult to regulate these bequests so that they might be concentrated sufficiently to produce an immediate result. But the figures show that generosity is a prominent feature of the American people, and that the needs of the country only have to be appreciated to have the funds forthcoming. We must make the need of research and of pure science felt in the country. We must live such lives of pure devotion to our science, that all shall see that we ask for money, not that we may live in indolent ease at the expense of charity, but that we may work for that which has advanced and will advance the world more than any other subject, both intellectually and physically. We must live such lives as to neutralize the influence of those who in high places have degraded their profession, or have given themselves over to ease, and do nothing for the science which they represent. Let us do what we can with the present means at our disposal. There is not one of us who is situated in the position best adapted to bring out all his powers, and to allow him to do most for his science. All have their difficulties, and I do not think that circumstances will ever radically change a man. If a man has the instinct of research in him, it will always show itself in some form. But circumstances may direct it into new paths, or may foster it so that what would otherwise have died as a bud now blossoms and ripens into the perfect fruit.

Americans have shown no lack of invention in small things; and the same spirit, when united to knowledge and love of science, becomes the spirit of research. The telegraph operator, with his limited knowledge of electricity and its laws, naturally turns his attention to the improvement of the only electrical instrument he knows anything about; and his researches would be confined to the limited sphere of his knowledge, and to the simple laws with which he is acquainted. But as his knowledge increases, and the field broadens before him, as he studies the mathematical theory of the subject, and the electro-magnetic theory of light loses the dim haze due to distance, and becomes his constant companion, the telegraph instrument becomes to him a toy, and his effort to discover something new becomes research in pure science.

It is useless to attempt to advance science until one has mastered the science; he must step to the front before his blows can tell in the strife. Furthermore, I do not believe anybody can be thorough in any department of science, without wishing to advance it. In the study of what is known, in the reading of the scientific journals, and the discussions therein contained of the current scientific questions, one would obtain an impulse to work, even though it did not before exist. And the same spirit which prompted him to seek what was already known, would make him wish to know the unknown. And I may say that I never met a case of thorough knowledge in my own science, except in the case of well-known investigators. I have met men who talked well, and I have sometimes asked myself why they did not do something; but further knowledge of their character has shown me the superficialty of their knowledge. I am no longer a believer in men who could do something if they would, or would do something if they had a chance. They are imposters. If the true spirit is there, it will show itself in spite of circumstances.

As I remarked before, the investigator in pure science is usually a professor. He must teach as well as investigate. It is a question which has been discussed in late years, as to whether these two functions would better be combined in the same individual, or separated. It seems to be the opinion of most, that a certain amount of teaching is conducive, rather than otherwise, to the spirit of research. I myself think that this is true, and I should myself not like to give up my daily lecture. But one must not be overburdened. I suppose that the true solution, in many cases, would be found in the multiplication of assistants, not only for the work of teaching, but of research. Some men are gifted with more ideas than they can work out with their own hands, and the world is losing much by not supplying them with extra hands. Life is short; old age comes quickly, and the amount one pair of hands can do is very limited. What sort of shop would that be, or what sort of factory, where one man had to do all the work with his own hands? It is a fact in nature, which no democracy can change, than men are *not* equal—that some have brains, and some hands. And no idle talk about equality can ever subvert the order of the universe.

I know of no institution in this country where assistants are supplied to aid directly in research. Yet why should it not be so? And even the absence of assistant professors and assistants of all kinds, to aid in teaching, is very noticeable, and must be remedied before we can expect much.

There are many physical problems, especially those requiring exact measurements, which cannot be carried out by one man, and can only be successfully attacked by the most elaborate apparatus, and with a full corps of assistants. Such are Regnault's experiments on the fundamental laws of gases and vapors, made thirty or forty years ago by aid from the French government, and which are the standards to this day. Although these experiments were made with a view to the practical calculation of the steam-engine, yet they were carried out in such a broad spirit that they have been of the greatest theoretical use. Again, what would astronomy have done without the endowments of observatories? By their means, that science has become the most perfect of all branches of physics, as it should be from its simplicity.

There is no doubt, in my mind, that similar institutions for other branches of physics, or, better, to include the whole of physics, would be equally successful. A large and perfectly equipped physical laboratory with its large revenues, its corps of professors and assistants, and its machine-shop for the construction of new apparatus, would be able to advance our science quite as much as endowed observatories have astronomy. But such a laboratory should not be founded rashly. The value will depend entirely on the physicist at its head, who has to devise the plan, and to start it into practical working. Such a man will always be rare, and cannot always be obtained. After one had been successfully started, others could follow; for imitation requires little brains.

One could not be certain of getting the proper man every time, but the means of appointment should be most carefully studied so as to secure a good average. There can be no doubt that the appointment should rest with a scientific body capable of judging the highest work of each candidate.

Should any popular element enter, the person chosen would be either of the literary-scientific order, or the dabbler on the outskirts who presents his small discoveries in the most theatrical manner. What is required is a man of depth, who has such an insight into physical science that he can tell when blows will best tell for its advancement.

Such a grand laboratory as I describe does not exist in the world, at present, for the study of physics. But no trouble has ever been found in obtaining means to endow astronomical science. Everybody can appreciate, to some extent, the value of an observatory; as astronomy is the simplest of scientific subjects, and has very quickly reached a position where elaborate instruments and costly computations are necessary to further advance. The whole domain of physics is so wide that workers have hitherto found enough to do. But it cannot always be so, and the time has even now arrived when such a grand laboratory should be founded. Shall our country take the lead in this matter, or shall we wait for foreign countries to go before? They will be built in the future, but when and how is the question.

Several institutions are now putting up laboratories for physics. They are mostly for teaching, and we can expect only a comparatively small amount of work from most of them. But they show progress; and, if the progress be as quick in this direction as in others, we should be able to see a great change before the end of our lives.

As stated before, men are influenced by the sympathy of those with whom they come in contact. It is impossible to immediately change public opinion in our favor; and, indeed, we must always seek to lead it, and not be guided by it. For pure science is the pioneer who must not hover about cities and civilized countries, but must strike into unknown forests, and climb the hitherto inaccessible mountains which lead to and command a view of the promised land,—the land which science promises us in the future; which shall not only flow with milk and honey, but shall give us a better and more glorious idea of this wonderful universe. We must create a public opinion in our favor, but it need not at first be the general public. We must be contented to stand aside, and see the honors of the world for a time given to our inferiors; and must be better contented with the approval of our own consciences, and of the very few who are capable of judging our work, than of the whole world beside. Let us look to the other physicists, not in our own town, not in our own country, but in the whole world, for the words of praise which are to encourage us, or the words of blame which are to stimulate us to renewed effort. For what to us is the praise of the ignorant? Let us join together in the bonds of our scientific societies, and encourage each other, as we are now doing, in the pursuit of our favorite study; knowing that the world will some time recognize our services, and knowing, also, that we constitute the most important element in human progress.

But danger is also near, even in our societies. When the average tone of the societies is low, when the highest honor are given to the mediocre, when third-class men are held up as examples, and when trifling inventions are magnified into scientific discoveries, then the influence of such societies is prejudicial. A young scientist attending the meetings of such a society soon gets perverted ideas. To his mind, a molehill is a mountain, and the mountain a molehill. The small inventor or the local celebrity rises to a greater height, in his mind, than the great leader of science in some foreign land. He gauges himself by the molehill, and is satisfied with his stature; not knowing that he is but an atom in comparison with the mountain, until, perhaps, in old age, when it is too late. But, if the size of the mountain had been seen at first, the young scientist would at least have been stimulated in his endeavor to grow.

We cannot all be men of genius; but we can, at least, point them out to those around us. We may not be able to benefit science much ourselves; but we can have high ideals on the subject, and instil them into those with whom we come in contact. For the good of ourselves, for the good of our country, for the good to the world, it is incumbent on us to form a true estimate of the worth and standing of persons and things, and to set before our own minds all that is great and good and noble, all that is most important for scientific advance, above the mean and low and unimportant.

It is very often said, that a man has a right to his opinion. This might be true for a man on a desert island, whose error would influence only himself. But when he opens his lips to instruct others, or even when he signifies his opinions by his daily life, then he is directly responsible for all his errors of judgment or fact. He has no right to think a molehill as big as a mountain, nor to teach it, any more than he has to think the world flat, and teach that it is so. The facts and laws of our science have *not* equal importance, neither have the men who cultivate the science achieved equal results. One thing is greater than another, and we have no right to neglect the order. Thus shall our minds be guided aright, and our efforts be toward that which is the highest.

Then shall we see that no physicist of the first class has ever existed in this country, that we must look to other countries for our leaders in that subject, and that the few excellent workers in our country must receive many accessions from without before they can constitute an American science, or do their share in the world's work.

But let me return to the subject of scientific societies. Here American science has its hardest problem to contend with. There are very many local societies dignified by high-sounding names, each having its local celebrity, to whom the privilege of describing some crab with an extra claw, which he found in his morning ramble, is inestimable. And there are some academies of science, situated at our seats of learning, which are doing good work in their locality. But distances are so great that it is difficult to collect men together at any one point. The American association, which we are now attending, is not a scientific academy, and does not profess to be more than a gathering of all who are interested in science, to read papers and enjoy social intercourse. The National academy of sciences contains eminent men from the whole country, but then it is only for the purpose of advising the government freely on scientific matters. It has no building, it has no library; and it publishes nothing except the information which it freely gives to the government, which does nothing for it in return. It has not had much effect directly on American science; but the liberality of the government in the way of scientific expeditions, publications, etc., is at least partly due to its influence, and in this way it has done much good. But it in no way takes the place of the great Royal society, or the great academies of science at Paris, Berlin, Vienna, St. Petersburg, Munich, and, indeed, all the European capitals and large cities. These, by their publications, give to the young student, as well as the more advanced physicist, models of all that is considered excellent; and to become a member is one of the highest honors to which he can aspire, while to write a memoir which the academy considers worthy to be published in its transactions excites each one to his highest effort.

The American academy of sciences in Boston is perhaps our nearest representation of this class of academies, but its limitation of membership to the State deprives it of its national character.

But there is another matter which influences the growth of our science.

As it is necessary for us still to look abroad for our highest inspiration in pure science, and as science is not an affair of one town or one country, but of the whole world, it becomes us all to read the current journals of science and the great transactions of foreign societies, as well as those of our own countries. These great transactions and journals should be in the library of every institution of learning in the country, where science is taught. How can teachers and professors be expected to know what has been discovered in the past, or is being discovered now, if these are not provided? Has any institution a right to mentally starve the teachers whom it employs, or the students who come to it? There can be but one answer to this; and an institution calling itself a university, and not having the current scientific journals upon its table or the transactions of societies upon its library-shelves, is certainly not doing its best to cultivate all that is best in this world.

We call this a free country, and yet it is the only one where there is a direct tax upon the pursuit of science. The low state of pure science in our country may possibly be attributed to the youth of the country; but direct tax, to prevent the growth of our country in that subject, cannot be looked upon as other than a deep disgrace. I refer to the duty upon foreign books and periodicals. In our science, no books above elementary ones have ever been published, or are likely to be published, in this country; and yet every teacher in physics must have them, not only in the college library, but on his own shelves, and must pay the government of this country to allow him to use a portion of his small salary to buy that which is to do good to the whole country. All freedom of intercourse which is necessary to foster our growing science is thus broken off; and that which might, in time, relieve our country of its mediocrity, is nipped in the bud by our government, which is most liberal when appealed to directly on scientific subjects.

One would think that books in foreign languages might be admitted free; but to please the half-dozen or so workmen who reprint German books, not scientific, our free intercourse with that country is cut off. Our scientific associations and societies must make themselves heard in this matter, and show those in authority how the matter stands.

In conclusion, let me say once more, that I do not believe that our country is to remain long in its present position. The science of physics, in whose applications our country glories, is to arise among us, and make us respected by the nations of the world. Such a prophecy may seem rash with regard to a nation which does not yet do enough physical work to support a physical journal. But we know the speed with which we advance in this country; we see cities springing up in a night, and other wonders performed at an unprecedented rate. And now we see physical laboratories being built, we see a great demand for thoroughly trained physicists, who have not shirked their mathematics, both as professors and in so-called practical life; and perhaps we have the feeling, common to all true Americans, that our country is going forward to a glorious future, when we shall lead the world in the strife for intellectual prizes as we now do in the strife for wealth.

But if this is to be so, we must now aim low. The problems of the universe cannot be solved without labor; they cannot be attacked without the proper intellectual as well as physical tools; and no physicist need expect to go far without his mathematics. No one expects a horse to win in a great and long race who has not been properly trained; and it would be folly to attempt to win with one, however pure his blood and high his pedigree, without it. The problems we solve are more difficult than any race: the highest intellect cannot hope to succeed without proper preparation. The great prizes are reserved for the greatest efforts of the greatest intellects, who have kept their mental eye bright and flesh hard by constant exercise. Apparatus can be bought with money, talents may come to us at birth; but our mental tools, our mathematics, our experimental ability, our knowledge of what others have done before us, all have to be obtained by work. The time is almost past, even in our own country, when third-rate men can find a place as teachers, because they are unfit for everything else. We wish to see brains and learning, cnmbined with energy and immense working-power, in the professor's chair; but, above all, we wish to see that high and chivalrous spirit which causes one to pursue his idea in spite of all difficulties, to work at the problems of nature with the approval of his own conscience, and not of men before him. Let him fit himself for the struggle with all the weapons which mathematics and the experience of those gone before him can furnish, and let him enter the arena with the fixed and stern purpose to conquer. Let him not be contented to stand back with the crowd of mediocrity, but let him press forward for a front place in the strife.

The whole universe is before us to study. The greatest labor of the greatest minds has only given us a few pearls; and yet the limitless ocean, with its hidden depths filled with diamonds and precious stones, is before us. The problem of the universe is yet unsolved, and the mystery involved in one single atom yet eludes us. The field of research only opens wider and wider as we advance, and our minds are lost in wonder and astonishment at the grandeur and beauty unfolded before us. Shall we help in this grand work, or not? Shall our country do its share, or shall it still live in the almshouse of the world?

French Tribute to Darwin.—The Committee of the Royal Society has requested the men of science upon the continent to join them in erecting a monument to Darwin. The French Academy accordingly appointed a committee to receive contributions, and M. de Quatrefages, in the name of M. Milne Edwards, who was absent on account of sickness, addressed the Academy in advocacy of the subscription. He stated, however, that the French committee wished to express no sentiment in regard to the scientific or philosophical teachings of Darwin, but that their homage was rendered to a man who consecrated his whole life to scientific work, who attacked successfully some of the most difficult problems of organic life, and who, by the special direction of his investigations and the success which often crowned them, rendered brilliant service to positive science.—*Les Mondes*, January 6, 1883. C.

Book Notices.

CONVERSION TABLES OF METRIC AND BRITISH OR UNITED STATES WEIGHTS AND MEASURES; with an Introduction by Robert H. Thurston. New York: John Wiley & Sons, 1883.

Professor Thurston has given to the public in this small volume quite a complete series of tables for passing from our old standards of weights and measures to the French system, and the reverse. They are compiled in part from accepted authorities. To an engineer who habitually consults French professional literature, or to any other person who finds himself obliged occasionally to convert French into English weights and measures, or who wishes only to familiarize himself with the French system, and desires something more elaborate than is obtainable from technical pocket-books, the little treatise in question will be welcome.

An introduction by the author precedes the tables, and is a short essay, neatly and concisely written, on standards in general. The metric system is advocated in it, and allusion is made to the difficulty of fully adopting this system in Great Britain and the United States. While to a scientific man the nomenclature of the French system appears simplicity itself, to the mass of an *English-speaking* people it sounds complex and foreign, and raises their prejudices. But the nomenclature of a new system of weights and measures is really of not much consequence, provided the system is good; and by retaining familiar denominations, with the prefix *new* put before them, a great obstacle is removed to the spread of the improved system. Thus, the new yard may be the meter, the new pound the half kilogramme, the new quart the liter. The subdivisions may be either according to the decimal or duodecimal enumeration, as may be preferred in the different vocations. In respect to the inconvenience which certain industries would experience from a change of weights and measures, it is a very small offset to the aggregate advantages attainable in the rest by the adoption of the metric system. Moreover, such industries may continue using the old standards until they can adapt themselves by gradual provision to the new order of things. After all is ready for a change let it occur at once. Improvements cannot be forsworn because some will suffer by them. How many have suffered by changes which they were powerless to prevent and too blind to foresee!

Momentary pangs accompany the first steps of a revolution, which need not be violent to be real, which may affect a whole people or a small trade. This is the law of progress; this is broadly the law of nature. A powerful conservative element may hold in check for some time a real advance; but meanwhile this gathers strength, and at last bursts suddenly through all opposition. Conservatism stands up for the purpose, chiefly of being knocked down sooner or later.

Lieut. Birnie's tables, as here given by Professor Thurston, appear adapted to all the requirements of the engineer. Those of Captain Noble are not so extensive, yet may better suit certain purposes. Additional tables by the author follow. Then the C. G. S. system of units is briefly considered. Finally the work closes with a short table of four-figure logarithms. C. E.

STUDY ON RESERVOIR WALLS, by J. B. Krantz. Translated from the French, by F. A. Mahan. New York: John Wiley & Sons, 1883.

This little work merits attention from the profession. Its author, M. Krantz, is a French government engineer, who, by his abilities, ranks high in his corps. As an introduction to the study of reservoir dams of masonry it serves its purpose very well; and those engineers also who have given attention to such structures, may find suggestions in it new to them. It advocates the superiority of the French form of cross-section, which consists of a level top and *curved* batters at the sides. The latter feature will not be viewed favorably by the generality of American engineers, prejudiced as they are against all curved work; but in this instance especially, as in some others, the prejudice is unfounded. The object in using batters curving more and more decidedly toward the bottom of the dam is, to concentrate economically the mass of material in this part of the section, where it scientifically belongs. Certain objections may, indeed, be urged even here against curved batters by an engineer who well understands his art; and in a few recent French dams they have consequently been omitted, although the shapes adopted approached closely to that deduced with them. Yet they are perfectly practicable in every way. As to the trouble in forming them, it is no greater than with broken or continuous straight batters.

A number of small plates, with dimensions in full on the figures, accompany this essay. About the first half of them give standard sections for dams of various heights; the remainder are comparisons between the standard sections and many old Spanish and French dams noted for their size and age. These comparisons are very instructive; for the old Spanish dams would to-day be repeated by so-called practical men; that is, by men who do not theorize. In the French form of section we see law, science, economy; in any of the Spanish sections we as clearly perceive uncertainty, bad disposition of mass, and enormous waste of material. The older French dams show the same defects, but not so grossly. The Furens dam in France, probably the highest as yet constructed, retaining at the deepest part a head of water of 164 feet when the reservoir is full, is built strictly upon the system advocated in this little work; and it is now sufficiently old to confirm the correctness of the principle of construction adopted C. E.

La Navigation Electrique, par Georges Dary, Paris. Librairie Polytechnique de J. Baudry, Editeur, 15 Rue des Saint-Pères, 1882, pp. 65.

This little book is very general in its title and is correspondingly particular in its subject matter, being an account of the apparatus devised by M. Gustave Trouvé for the propulsion of pleasure boats by electricity, with a brief reference to the experiments of M. de Jacobi in 1839 in St. Petersburg, and of M. de Molins twenty years later in Paris, and a suggestion of the possibilities of the use of an electrical motor for aerial navigation. The apparatus of M. Trouvé consists of a screw placed in a recess in the rudder, the motor being placed upon the rudder-head, and the steering cords being the conductors, and it can be applied to any boat by simply unshipping the ordinary rudder and substituting this one in its place.

The motor consists of a Siemens armature with some modifications, by which he claims to have increased the effective part of the revolution and correspondingly reduced the dead part; and he uses an electro-magnet instead of a permanent magnet, which motors he combines, so that two or more of them act together, while he can use one at a time for less speed when desired.

He uses a sulpho-chromic battery with some special details of construction, which, like those upon the motor, are ingeniously devised for convenience of use and economy of space. It is stated that in 1881, he made, on the Seine, an average speed of from five to six knots per hour. G. M. E.

FORMULAIRE PRATIQUE DE l'ÉLECTRICIEN; PREMIERE ANNEE, 1883. E. Hospitalier. Paris: G. Masson, 1883.

The two hundred and seventy-eight closely printed pages of this little book contain a mass of information, of so convenient and suggestive a character as fully to justify its aim to be the practical electrician's *vade mecum.* In the first of the five main divisions of the book is given a concise statement of the general laws regulating electrical and magnetic action. The second treats of the units of measurement, and also contains tables showing the mutual relations between the numerous practical units now used in electrical mechanics. The third part, with the assistance of neat illustrations, is devoted to the instruments, and methods used in measurement. The fourth contains practical directions, mathematical and physical tables, and a goodly collection of the latest experimental results in the various departments of applied electricity. The concluding part is devoted to receipts and processes of advantage in manipulation and construction.

In a work that aims to be comprehensive and yet to represent the science of the hour, there must always be found something the reader would like to see improved in form or in fact. Why, for example, should not the late values for the velocity of light by Newcomb and Michaelson be inserted along with the old French results? And so a list of minor improvements might be suggested which would add both to its scientific and international character. We prefer, however, to respond to the auhor's direct invitation to suggestion, to offer one of a more general nature. The brief description of methods, instruments, results, etc., are given with but a very few references to the publications where they were first described. While this has the advantage of brevity, an appendix of say twenty pages of references to the *original papers,* or even to more comprehensive treatises would not add much to bulk, and would, moreover, make this formulary a much more valuable book for the general student, and not less so for the practical man. In fact, with such addition, it would be difficult to find a work better suited to outline a course of instruction in the Electrical Engineering required by present science and practice. M. B. S.

ELECTRO-MAGNETS: the Determination of the Elements of their Construction; by T. H. Du Moncel (tr. from 2d ed.) Van Nostrand's Science Series, No. 64. New York: D. Van Nostrand, 1883.

The increasing importance of the electro-magnet as an industrial appliance makes this reproduction of M. Du Moncel's investigations timely. These researches belong to that daily enlarging class whose aim is to make the mathematical laws of electrical action available in the actual construction. Those interested will here find convenient formulæ, numerically illustrated, for computing the elements of the electro-magnet, best suited to the varying conditions of practice—particularly telegraphic practice. We regret to note that the resistances are not, as a rule, given in the recognized units. M. B. S.

DYNAMO-ELECTRIC MACHINERY; a series of Lectures by Sylvanus P. Thompson, B. A.; D. Sc.; M. S. T. E. With an Introduction by Frank L. Pope, M. S. T. E. Van Nostrand's Science Series, No. 66. New York: D. Van Nostrand, 1883.

There have not been wanting, in recent years, special works describing, in a general, and sometimes, indeed, in a tediously minute manner, the various forms of dynamo machines proposed by inventors. We have, however, in these three able lectures of Prof. S. P. Thompson, an entirely novel treatment, one truly philosophic and consequently also comprehensive. Dynamos are not only classified, according to the theory of their construction, but are again arranged in classes, according with the various methods of their use. This plan, followed out in detail allows a scientific discussion of advantages and disadvantages in particular forms, as well as a clear presentation of the ideals demanded by theory.

We cannot dismiss this opportunity of calling attention to a neat mathematical discussion in the last lecture concerning the "maximum efficiency" of the dynamo as a motor. It had been shown by Siemens that the "maximum rate of doing work" does not necessarily conduce to "maximum efficiency." This point is not only analytically developed by Prof. Thompson, but the relation between the laws of Jacobi and Siemens is also illustrated geometrically. M. B. S.

Iron Watches.—Messrs. Crowther Bros. & Co., of Kidderminster, in order to prove the malleability and ductility of their iron, have constructed a watch entirely of iron, which keeps excellent time. Claudius Saunier, on reporting this fact in the *Revue Chronométrique,* adds: There is nothing new under the sun. We have a watch upon which is engraved the date of 1504, and in which all the wheels and pinions are made of iron.—*Les Mondes,* December 30. 1882. C.

Conservation of Solar Energy.—Duflos de Senlis has addressed a letter to the *Revue Scientifique,* in which he claims that the solar heat must always have been the same as it is now. He starts from the principle that all the heat which is radiated from the sun returns to it under some form or other. The sun, in his opinion, may be compared to an incandescent electric lamp working in an absolute vacuum, and the arguments which have been adduced in favor of a gradual concentration of the sun do not appear to him to be well grounded.—*Les Mondes,* January 6, 1883. C.

Elephant's Milk.—Dr. Quesneville states that elephant's milk resembles cream, but it has not the consistency of ordinary cream. When seen in the microscope the globules are large, transparent, and sharply outlined. The cream rises rapidly, leaving the milk of a bluish tinge. The fatty matter has a yellow color, similar to that of olive oil; liquid at ordinary temperature, it solidifies at —18° (—0°4 F.). The odor and taste are very pleasant. The reporter of *Les Mondes* looks forward to the day when some bold speculator will milk elephants in the streets of Paris, in order to offer glasses of the milk to amateurs, and predicts a brilliant success to the first one who will try the experiment.—*Les Mondes,* January 6, 1883. C.

Cyclonic Theory of Sun Spots.—Faye cites Young's objections to his cyclonic theory on the ground that the velocity of solar rotation is so small that it would not be sufficient to produce a cyclone. He refers to the hydrodynamic law, that the angular velocity in a whirlwind varies in the inverse ratio of the square of the distance from the axis, and he names the following distinctive characteristics of gyratory movement, which are found upon the sun as well as in our atmosphere. 1. The circular form of all the spots when they first make their appearance. 2. The conical form of their opening. 3. The great contraction of the opening at a lower level. 4. Their tendency to enlarge while still preserving a circular form. 5. Their tendency to subdivide into partial spots, which become complete spots with a penumbra, nucleus, and dark centre. 6. Their regular movement in the direction of the current in which they originate. 7. Their long duration, which implies a gyration around a vertical axis. 8. Their mode of disappearance, which corresponds to that of whirlpools upon the face of the earth. 9. The reappearance of hydrogen around the spots, as if it had been absorbed at the centre and thrown out at the circumference.—*Comptes Rendus,* December 26, 1882. C.

Nitrogen in Soils.—J. B. Lawes, in a long communication upon agriculture, advocates the opinion that the source of all the nitrogen which is contained in crops is found in the soil itself and in the manures which are supplied. Although the experiments at Rothamsted may not yet have established this theory beyond controversy, they have given strong indications of its truth, and he thinks that future operations will demonstrate it conclusively. He regards it as fortunate for agriculture and encouraging to those who are engaged in it, that the stock of nitrogen, even in a subsoil which is comparatively poor, is so large as to show very little diminution after cultivation for a long series of years.—*Bull. de la Soc. d'Encour.*, November, 1882. C.

Propellers of Manganese Bronze.—The resistance of manganese bronze is greater than that of the best ordinary bronze or of cast steel. The wings of propellers can, therefore, be made much lighter than usual, and the resistance of the water largely reduced. Moreover, the manganese bronze comes from the mould in the exact shape which is desired, and there is no danger of change by the process of annealing, which is required for steel. In the third place, the corrosion to which steel is subject and which requires frequent renewals, is entirely avoided. The manganese bronze preserves a perfectly clean and smooth surface for an indefinite time. It is a little more expensive than ordinary bronze, but the difference in price is largely compensated by the difference of resistance, which allows the employment of a smaller amount of material. It costs about twice as much as steel, but in consideration of the frequent renewals of steel the manganese bronze is eventually cheaper. The objection that manganese bronze might produce a prejudicial galvanic action has not been sustained by any authentic observations.—*Chron. Industr.*, January 1, 1883. C.

Solar Eclipse of May, 1883.—In a report to the *Bureau des Longitudes*, M. Janssen speaks of the favorable circumstances which will attend the approaching eclipse of the sun. Among the questions which it may perhaps enable us to solve are the following: 1. Are the appendices of the cornea parts of a solar atmosphere, or are they merely swarms of meteorities circulating about the sun? 2. Is the zodiacal light due to an independent body, or is it connected with the cornea? 3. Are there planets between Mercury and the sun, and are the anticipations of Leverrier to be confirmed within the planetary belt as they were at the outer limits of the belt? There are two ways of studying the last question—by a careful examination of the sun's surface, or by an exploration of the circumsolar regions when an eclipse renders such explorations possible. The second method seems the most efficacious when an eclipse is long enough to allow a minute examination. The eclipse of May 6th will last 5 minutes 59 seconds, which is three times the duration of ordinary eclipses. It will, therefore, present unusually favorable conditions for investigation. He recommends that the *Bureau* should send out an expedition by way of New York, crossing the American continent to San Francisco, and there taking a steam packet to the Marquesas Islands. There, a French ship-of-war should take the exhibition to Caroline and Flint Islands, which are both near the central line of the eclipse.—*Les Mondes*, December 30, 1882. C.

Striking the Hours by Electricity.—J. Laugé, a watchmaker of Béziers, takes the electric wire of a battery which controls an electric bell, and attaches it to some metallic part of the movement of a clock. The positive wire, suitably insulated from other parts of the clock, is fastened, so that its extremity will be just over the handle of the hammer. When the clock strikes the hammer rises, and its handle rubs the positive wire, so as to form the contact. At the same moment, the other bells which are in the circuit strike the same hours as the clock. The system might be applied to church bells. Even the great bell of Notre Dame might be swung by a little clock, so as to strike synchronously with it, by means of a sufficiently powerful electro-magnet.—*L'Electricien*, No. 40. C.

Adulteration of Food.—The municipal laboratory of Paris during the two years of its existence has rendered valuable service to the citizens. Those who practice the adulterations often display an amount of skill which would be more than sufficient to gain an honest fortune. The manufacture of spurious gooseberry jelly furnishes an example. The jelly is made from seaweed, the color from fuchsine, or some other similar material, and the flavor is given by a compound in which there is not a drop of gooseberry juice, but which is composed of 5 parts acetic ether, 4 parts tartaric acid, 1 part benzoic acid, 1 part succinic acid, 1 part aldehyde and œnantic acid. M. Girard, the director of the laboratory, gives also the composition of nine other chemical compounds for imitating the flavors of strawberry, pineapple, melon, apple, pear, cherry, peach, apricot and plum. Flour is exposed to dampness, in order to make it weigh heavier; the gluten is thus altered, being rendered less fit for breadmaking and more liable to mould. Wheat flour is mixed with flour of beans, peas, lentils, maize, and even with potato starch. The most guilty adulteration consists in mixing with flour mineral products which are often poisonous, such as lead, copper, zinc, sulphate of lime, and chalk. Flour has been imported into France from Rotterdam, which contained as much as 30 per cent. of plaster, or as much as 20 per cent. of sulphate of barytes. Out of thirty-one specimens of flour which were examined at the laboratory only thirteen were found to be pure.—*Les Mondes,* Nov. 25, 1882. C.

Preservation of Honey.—According to Vogel, honey contains about one per cent. of fornic acid on the average. E. Mylins observed that crude honey kept better than that which had been clarified; hence he was led to try the addition of formic acid, and the result was very satisfactory. The acid seems to hinder fermentation, without altering the taste of the honey.—*Les Mondes,* April 14, 1883. C.

Water Motor for Clock Work.—M. Tillae, of Tulle, has devised a drum which is divided into an equal number of cells, arranged around a central arbor. A quantity of liquid is introduced into the interior of the drum, sufficient to fill about two of the chambers, and a cord to which a weight is suspended, is rolled around the arbor. The liquid is then raised on the opposite side until equilibrium is established. The cells communicate by small orifices, near the circumference of the drum, so that the liquid tends to flow constantly downward while the weight tends to carry it upward. The amount of liquid and the weight can be so adjusted as to obtain a rotary movement as slow as may be desired.—*Les Mondes,* April 14, 1883. C.

Use of the Palmetto.—The constant increase in the demand for paper, cordage, and woven fabrics, stimulates the search for fibrous materials which may be used in the place of rags and straw. In Algiers, by the side of the Alfa and Ramie grows a plant which is not less valuable for its textile properties; it is the dwarf palm tree, a wild plant greatly dreaded by agriculturists. The Arabs have long known the fibrous properties of this shrub; but they have never utilized any portion but the leafy tops. A Frenchman, M. Reynaud, has found a use for the entire plant; the roots being employed for heating, and all the rest being transformed into fibres of a superior quality.—*Chron. Indus'r.,* March 25, 1883. C.

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Sessão publica. June, 1880.
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Almanaque Nautico para 1883 y 1884.
Presented by El Instituto y Observatorio de Marina de la Ciudad de San Fernando.

American Journal of Railway Appliances. New York, 1883.

American Society of Mechanical Engineers. Transactions. Vols. 2 and 3. 1881 and 1882. New York.
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American Water Works Association. Report of Third Annual Meeting. Buffalo, 1883. Presented by the Association.

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Blake Manufacturing Company's Illustrated Catalogue of Pumps and Pumping Machinery. New York, 1883.
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The Phonetic Journal, by Isaac Pitman (with a single exception the only complete set in the United States), which will be highly appreciated by those interested in the question of spelling reform; of

The French Patents as far as published by the French Government; and of all the Coast Survey Charts thus far published by the United States Government.

E. HILTEBRAND, *Librarian.*

Franklin Institute.

[*Proceedings of the Stated Meeting, held September* 19, 1883.]

HALL OF THE INSTITUTE, Sept. 19, 1883.

The meeting was called to order at the usual hour, with the President, William P. Tatham, in the chair. There were present 91 members and 10 visitors.

The minutes of the last stated meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting of the Board, held Wednesday, September 12th, 20 persons had been elected to membership in the Institute.

The President gave an account of the present condition of the work upon the International Electrical Exhibition, which the Institute proposes to hold in September, 1884.

The special committee appointed to revise the existing method of presenting papers for reading and discussion at the meetings, made the following report, viz.:

Report of Joint Committee of Meetings and Publication, on the Reading of Papers before the Institute.

The suggestions submitted to this committee relate to two distinct subjects—that of greater interest and usefulness in the monthly meetings, and that of reporting such discussions as the papers read may evoke. To accomplish the first and more important purpose it is proposed to do away, as far as possible, with mere matters of business at the monthly meetings, to shorten the time allowed for the reading of papers, to require that the latter shall be actual essays prepared beforehand and not impromptu speeches, and to have slips of such papers printed before the meeting and circulated among members interested in the subject, that they may be prepared to discuss it intelligently.

To effect the changes suggested it is necessary to amend the By-laws in Article XIII, relating to the order of business. The amendments proposed have the effect of postponing the routine business matters until after the reading of papers, etc., so that the discussion of subjects of scientific and mechanical interest shall have the preference. If then, there should not be time for the transaction of business, special meetings may be held, if necessary, to attend to such matters. The amendment proposed is as follows:

Strike out Section 2 of Article XIII, and insert as follows:

Section 2.—The order shall be as follows:

1. Reading of Minutes.
2. Secretary's report of progress in science and the arts.
3. Paper or papers announced for the evening, followed by discussion thereon.
4. Secretary's report on exhibits of new inventions.
5. Reports from the Board of Managers.
6. Reports from the Standing Committees.
    (1.) On Library.
    (2.) On the Cabinet of Minerals.
    (3.) On the Cabinet of Models.
    (4.) On the Cabinet of Arts and Manufactures.
    (5.) On Meteorology.
    (6.) On Meetings.
    (7.) On Science and the Arts.
    (8.) The Curators.
7. Reports from Special Committees.
8. Reports from Sections.
9. Deferred business.
10. Consideration of new business.

Section 3.—Not more than twenty minutes shall be allowed for the reading of a paper, and the discussion thereon shall be limited to forty minutes, no speaker being allowed more than ten minutes.

Change the numbers of Sections 3 and 4, to 4 and 5.

The following rules of procedure have been adopted by the Committee on Meetings and Publication, viz:

One member of the Committee on Meetings and one of the Committee on Publications shall be appointed to act each month as readers, and determine provisionally, each for his committee, whether the papers submitted shall be read and printed in the Journal. If they agree, and the Committee on Meetings approves, the Secretary shall have the paper set in type, and fifty galley slips thereof taken, ten of which shall be retained in the library until after the reading, for the use there of members, and the remainder shall be distributed to such members as may apply for them until the stock, less the ten to be retained, is exhausted. The Secretary shall give notice on the notices of the meeting, of the title of the paper and of the printing of the slips. If the paper is to be read, but not printed in the Journal, slips may be printed and distributed as above at the expense of the author. If the paper is to be printed but not read, the members will receive it in the Journal, and no other printing is to be permitted. The paper must be submitted to the Secretary not less than ten days preceding the meeting at which it is to be read, and he shall immediately send it to the representative of the Committee on Meetings for the month. The latter shall submit the paper, after he has passed upon it, to the representative of the Committee on Publication for the month, in time to allow the latter to return the paper on, or before, the second Wednesday of the month. The paper shall be reported to the Committee on Meetings, which shall take final action as to the reading. If slips are to be printed, the Secretary shall have them ready for the members on the Monday preceding the monthly meeting.

The members shall serve as representatives in rotation, in an order determined by the chairman. In case of absence or inability of the representative to attend to his duties, the next on the list shall be notified by the Secretary to act in his place, and so on through the list.

The Committee on Publication may review the action of their reader and reject a paper finally, but his approval shall be sufficient to authorize the printing of galley slips.

In respect to reporting the debates, we find that no action is required by the committee or Institute. The By-laws, Section 2 of Article VII, prescribe as one of the duties of the Secretary that he shall report or cause to be reported the proceedings of the Institute and shall deliver the report thereof or an abstract of it to the editor for publication. The committee, however, would suggest to the Secretary that in the exercise of this power, he have full reports made of the discussions and printed on the type-writer for preservation in the library. Those which are deemed of sufficient importance may be printed in full in the Journal, and of the others, abstracts can be printed.

They would also recommend that to put the changed programme into operation at once, the order of business be temporarily changed by vote at the September meeting in accordance with these suggestions. Also, that the following resolution be submitted to the Institute at the September meeting:

Resolved, That the Secretary be authorized to provide an automatic signal bell that can be set to ring at an appointed time, and that when a speaker begins to read his paper it shall be his duty to set the bell to ring at the end of twenty minutes, after which signal the reading shall be stopped, unless unanimous consent is given the speaker to continue.

Under the proposed plan an essayist having a paper he desired to read would have to send it to the Secretary ten days before the meeting. The readers for the month would have three days in which to consider it at their leisure, not being required to meet for the purpose. The paper would then be submitted to the Committee on Meetings at its meeting on the second Wednesday evening. Action there would be final as to its reading and printing on galley slips, the Secretary being thus given four working days in which to have it set in type, and the members two days in which to read and consider it before the meeting. The Committee on Publication would in the meantime or afterwards review the action of their reader. This should secure well-digested papers and intelligent discussion.

On motion of Mr. Hector Orr the consideration of the report was postponed until the October meeting. .

A paper by Mr. Joseph Sharp, of Cincinnati, on "Oil-Dressed Belting," was read, in the absence of the author, by the Secretary. The paper was discussed by Messrs. J. W. Nystrom and Hugo Bilgram. It appears in the JOURNAL for October.

A paper by Mr. Robert Grimshaw, on "The Indicator as a Detector of Lost Motion," was read by title. It appears in this issue of the JOURNAL.

The Secretary's report comprised a review of the present condition of several important engineering projects, and a description of a number of new inventions, among which were included the following: The Blackman Exhaust Fan, an apparatus designed for ventilating purposes, and which is claimed by its makers to embody several features of construction, which add greatly to its capacity, utility, and economy, as compared with other devices for the same purpose. A new Reversing Gear for locomotive and other engines, invented by Fred. Rock, of Homer, N. Y., and the object of which is to supersede the link motion and other devices used for reversing or shortening the travel of the valve, to cut off steam at different parts of the stroke of the piston, in order that the steam may be used expansively at any time when the full stroke is unnecessary. An improved portable Fire-Escape, invented by H. H. Little, of Camden, N. J., composed of a series of extension-ladders connected with a lazy-tongs mechanism, by which they may be rapidly extended to full length and lowered, in which latter state the whole apparatus is compactly folded up. The actuating mechanism is a spring, the coiling of which lowers the apparatus; while releasing it, by the withdrawal of a pawl from a ratchet wheel which it carries, extends the apparatus to its full height. From the top of each ladder lateral platforms extend, which may be inclined so as to bring them opposite the windows of a building, and by means of which persons may pass from the windows to the ladders. A basket may also be raised and lowered by means of ropes passing over pulleys on the projecting arms of the upper section. The whole apparatus is mounted on a truck, which enables it to be rapidly transported and moved into any position with reference to a burning building where it may be needed.

The so-called "Calorific Positive Pump," invented by Mr. C. L. Riker, of New York, was exhibited in operation, and may be described in general terms as follows:

A steam generator contained within a cylindrical base, using gas as fuel, supplies steam to a copper cylinder situated above it, displacing the water contained therein until about three-quarters of its contents have been driven out, when the steam is suddenly condensed, forming a vacuum therein, the result of which is that the cylinder becomes again filled with water from the well, cistern or other source of supply. The above operation is then repeated. It should be stated that the pump is filled with water before it is started, after which it will always keep itself supplied and, if necessary, will work continually until either the water or gas fails to supply it. There are no working parts except the check valves in the suction and discharge pipes. It is an alternating vacuum and steam pressure pump, entirely automatic, after the ignition of the gas. It vaporizes at each discharge about one tablespoonful of water (for No. 5 size), and the construction is such that it is impossible to generate a greater amount of steam than is just sufficient to effect each intermittent discharge.

The consumption of gas is said to be 20 cubic feet per hour for 200 gallons of water raised 50 feet high.

Specimens of the so-called "Magneso-Calcite," a new fire-proof material, manufactured by the Magneso-Calcite Fire-proof Company, of Boston, were shown and described. The material, which takes the form of slabs, sheets, etc., of any desired form, consists of a number of layers of fibrous materials (mineral or vegetable), thoroughly incorporated, with the aid of water, with clay, magnesia, lime, talc, or similar refractory materials.

This is made into layers, sheets, or any other desired form, and is then saturated with a solution of a salt of lime, alum, borax, silicate or tungstate of sodium, or other incombustible salt. Thus prepared, the sheet, slab or what not, is covered on one or more sides with a lining made preferably of vegetable or mineral fibre, or a mixture of both, saturated with a solution of a salt of lime, alum, borax, tungstate or silicate of sodium.

Though its principal application, as stated by the makers, is as a lining to fire-proof safes and safety boxes, it is also recommended as a lining for vaults, floors, shutters, partitions, elevator shafts and hallways, for encasing boilers, fire-rooms in dwellings, stores and steamboats, covering steam pipes, etc., and, in short, in every situation where the use of a material possessing eminent heat-insulating and heat-resisting qualities is indicated.

A series of bevel-gear wheels, made by the system and machine described, some time since, in the JOURNAL, by Mr. Hugo Bilgram, was shown on behalf of the maker.

The "Balanced Thermometer," invented by Messrs. H. C. Kirk & J. T. Brayton, was exhibited for the maufacturers, the Geneva Balanced Thermometer Company, of Geneva, N. Y. A graduated mercurial tube of the ordinary pattern is balanced on needle points, the tube itself acting as a pointer on a dial carefully constructed for the purpose. The pointer being once adjusted to indicate the same temperature as shown by the mercury in the tube, the weight of the mercury will afterward determine the direction of the pointer and show the temperature.

The indications of these instruments may be read at a distance. They are made to register from 40 below zero to 140° Fah., and are extremely sensitive.

Several forms of sewer traps were shown and described on behalf of the inventors, Herman Pietsch, of Flatbush, L. I., and Joseph Bennor, of Philadelphia, respectively.

Prof. M. B. Snyder, seconded by Dr. Wahl, at the conclusion of the Secretary's report, offered the following resolutions, which were adopted without dissenting voice, viz.:

"*Resolved*, That a suitable committee be appointed to arrange, if possible for an 'International Electrical Congress,' to convene in Philadelphia on the occasion of the International Electrical Exhibition of 1884; also,

"*Resolved*, That said committee may, both prior to and during the Exhibition, arrange for conferences of scientific men interested in the various departments of pure and applied science."

The meeting was thereupon adjourned.

WILLIAM H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVI. NOVEMBER 1883. No. 5.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

FINAL REPORT OF THE SPECIAL COMMISSION TO INVESTIGATE THE WATER SUPPLY OF THE CITY OF PHILADELPHIA.

Philadelphia, April 5, 1883.

To the Select and Common Councils of the City of Philadelphia.

GENTLEMEN:—The undersigned have the honor to submit a final report upon the subjects referred to them, concerning the present and future supply of water for the City.

In the preliminary report made October 14, 1882, which your Board considered imperatively required in order that the City might avoid a short supply of water, certain recommendations were made for pumping machinery and mains, and for the construction and completion of reservoirs of distribution.

They have carefully revised the recommendations then made, and after a prolonged study of the subject, find no reason to change them in any essential particular.

In view, however, of the small amount immediately available for extensions, they recommend certain modifications in the application of the funds.

The resources understood to be available, and at the command of the Water Department, are as follows:

1. Appropriation of December 30, 1882, For the extension of Works...........................	$65,000 00

2. Appropriation of March 24, 1883, For the extension of Works	250,000 00
3. Appropriation of March 30, 1883, For the extension of Works	210,000 00
Total	$525,000 00

Which sum is now at the service of the Water Department.

The conclusions of the Board as to the most advantageous application of this sum are set forth in the following schedule:

SCHUYLKILL WORKS.

For engine and boiler house	$50,000 00
" two 15 million gallon engines	96,000 00
" two ranges of boilers and connections	65,000 00
" two 36-inch forcing mains, 2,500 L. feet at $15	37,500 00
" completing the laying of the 48-inch main to Corinthian Basin, 1,000 feet at $5	5,000 00
Cross connection from Corinthian Basin to Schuylkill and Fairmount Basin, 36-inch pipe	7,000 00
Tracks, coal-bins, etc	3,000 00
Total	$263,500 00

ROXBOROUGH.

For one 7½ million gallon engine	$47,000 00
" forcing mains, etc	3,000 00
" two boilers and steam pipe connections	7,000 00
" stack	2,000 00
" new Inlet, etc., screens and dredging	3,000 00
Total	$62,000 00

GERMANTOWN MAIN.

For 16-inch main, from Mount Airy reservoir on Allen's lane, to McCallum, McCallum to Carpenter, Carpenter, down Green to Tulpehocken	11,000 feet	
For 12-inch main on Green street, from Tulpehocken to Manheim street	6,500 feet	
	17,500 feet	
Total		$70,000 00

FRANKFORD.

For one 10 million engine	$47,000 00
" foundations	2,500 00
" steam connections	500 00
Total	$50,000 00

SURVEYS.

For Determining Sources of Future Supply.

For 2 parties per month (1 party per month at $1,000)	$ 2,000 00
" 6 months field work	12,000 00
" Analyses	1,000 00
" Office work	7,000 00
Total	$22,000 00

RECAPITULATION.

Amount available		$525,000 00
For Schuylkill Works	$263,500	
Germantown Mains	70,000	
Roxborough	62,000	
Frankford	50,000	
Surveying	22,000	467,500 00
Leaving a balance of		$57,500 00

Of which thirty-nine thousand five hundred (37, 500) dollars should be transferred to Item 15 of the annual appropriations for "buildings, grounds and reservoirs," and the remainder, twenty thousand (20,000) dollars, be allotted to the general contingencies of the Department.

The Board would modify the recommendations previously made in regard to the character of the machinery to be obtained, to suit the altered circumstances of the case. They advise for the Schuylkill and Roxborough Works, horizontal compound duplex engines, in general character similar to the Worthington engines at those works; and for Frankford Works, a compound rotating engine, of a form in some respects modified from that already in use.

The importance of the appropriation for the Germantown main is due to the imperfect supply in Germantown, the lower part of which is almost without water, and its population depending on one small main. At the same time the water supply as far south as Allegheny avenue will be greatly improved.

The appropriation for "buildings, grounds, and reservoirs," is necessary on account of the small sum allotted to this item in the appropriation bill for the current year, wherein only eighteen thousand five hundred (18,500) dollars is made to cover items specifically named, amounting to fifty-four thousand two hundred and twenty (54,220) dollars, and further by the dangerous condition of some of the reservoirs demanding immediate attention.

At Wentz Farm, the slip of the bank and other defects have reduced the present capacity to less than half of the total contents, as only twelve feet of water can be carried in the lower area, as against twenty-two feet, which could be maintained were the basin in good order. At other reservoirs, also, repairs are at once required to prevent rapid deterioration.

The item of contingencies is important to provide against variations in cost from the estimates, for additional works which cannot now be estimated for, and to enable the Department to deal promptly and efficiently in the event of accident. Your Board regard as indispensable to the satisfactory working of the Department, that a contingent fund should annually be at its disposal.

RESERVOIRS.

In the foregoing schedule no provision is made for the reservoirs mentioned in the preliminary report. It was there stated, as to the completion of East Park, the acquisition of land for and the construction of Cambria, and the acquisition of land for and the extension of Mt. Airy, that "all of them are needed now, and will ultimately form proper centres of distribution, whatever may be the permanent source of supply for the city."

This remark is based upon the fact that the vast extent of territory to be supplied with water in the city, and the diversified character and altitude of its surfaces, point out certain locations as peculiarly fitted for points of distribution independently of the source of supply. It is not probable that better points could be selected now if the whole subject were an open one. The city has already expended large sums at East Park, and a storage for its levels of distribution of from fourteen to sixteen days' supply can be had by completing it, at far less cost than in any other way. The location at Cambria and Thirtieth streets is as yet unimproved, and unless speedily acquired may be reached by building enterprises which will render it more difficult and expensive to obtain at a future time. There seems to be no better site for a reservoir to command this district, which already contains two hundred and thirty thousand persons, is now without any subsiding reservoir, and is growing more rapidly than any other part of the city. Adjacent to Mt. Airy Reservoir unimproved land can be had of suitable character and elevation at less cost than in the future. Its necessity for that section of the city is apparent when the small and totally inadequate dimensions of the present reservoir are considered.

Your Board would therefore again most urgently press upon your consideration the importance of immediately taking steps to acquire the needed land at the two points named, even if, as they are advised, no money is, at the moment, available for proceeding with the work of construction.

FUTURE SUPPLY.

Upon this most important branch of the subject your Board have bestowed much attention. But, owing to considerations hereinafter referred to, they find it impracticable at the present time to reach definite conclusions, or to submit any recommendations other than those embodied in this report.

In the preliminary report the following remarks were made:

"Meanwhile your attention is respectfully called to the fact that complete surveys must be made, and reliable data obtained, of the localities from and through which a pure water supply can be drawn, in order to form a correct judgment as to their availability. As it is essential that this information be obtained, an appropriation for such surveys of not less than fifteen thousand (15,000) dollars is suggested."

No steps having been taken in this direction by your Honorable bodies, it becomes necessary to again invite your attention to the subject, and your Board have included in their estimates for present expenditures, the sum of twenty thousand (20,000) dollars, which will enable the Department to place in the field, at once, surveying parties, and to work up the results of their labors. Under the most favorable conditions, the greater part of a year will be consumed in procuring the information, without which no intelligent judgment can be formed.

Indeed, in other cities large sums are annually expended for surveys to secure fresh information respecting the possible ssurces of water supply.

Recommendations heretofore presented for the supply of Philadelphia from distant points have, in the opinion of the Board, been based upon insufficient definite knowledge, and more recent investigations have shown, that in estimating the available rainfall and the effect upon the purity of the water of impounding it for long periods, views formerly entertained require considerable modification.

There are two main sources of supply, the Schuylkill and the Delaware, with their respective tributaries. At certain points each of these rivers furnishes an adequate amount of reasonably pure water.

At the points where the water for the city is now drawn, its impurity is constantly increasing, and is probably approaching the limit of wholesomeness.

The first inquiry, then, is clearly whether this impurity can be removed, or reduced to a safe point. If it can be so reduced, the present sources of contamination removed and guarded against for the future, and sufficient quantities be had, it is unnecessary to look to more distant sources. If this cannot be accomplished it will be needful to draw from one or the other of these rivers at points higher up.

To answer this inquiry, and to form a judgment of the cost either of purifying the present supply, or obtaining a new one, careful detailed analyses must be made of the water obtained from different points in order to trace the causes of impurity, as well as careful topographical and geological surveys. Gaugings of the streams, and of the rainfalls over the areas draining into the Perkiomen, Skippack, Wissahickon, etc., are required, as well as the upper affluents of the Delaware, if such should be found necessary. The surveys should be especially directed to ascertaining where, to what extent, and at what cost, impounding reservoirs can be constructed, and the several available routes for conduits carefully investigated, with a view to determine their cost.

At present the larger portion of the city's supply is drawn from the Schuylkill. It is evident that, so far as quantity is concerned, an abundant supply can be obtained for a long time to come, for its minimum flow is not less than two hundred million gallons daily, and this might be largely increased by additional dams, as was suggested by the Park Commission sixteen years ago, and by the Board of Experts in 1875.

Formerly, the character of the Schuylkill water was of the first rank among the sources of supply for cities. If this condition could be restored, nothing better can be expected.

The first duty of the city is to remove whatever sources of contamination are imported within its own limits. The city's ownership of so much of the banks of the river as are contained in Fairmount Park is of the greatest importance in this respect, but the efforts of the Park Commission to preserve the purity of the water have been rendered almost nugatory by the constantly increasing drainage into the river from the east bank, caused by the growth of large manufacturing industries, and their attendant populations.

Your Board believe that analyses will show that the deterioration in the quality of the Schuylkill water, justly complained of, is largely due to this cause, and that the completion of the sewer from Flat Rock to below Fairmount will tend to restore its wholesomeness by removing a most serious source of pollution. The construction of this sewer has for many years been urged upon the city authorities, first, by the Park Commission, and subsequently, by others who have considered the subject, and it is a matter for congratulation that the work is at last to be undertaken.

Supposing, however, that when this sewer is in use, and when the city has exhausted all other means of preventing contamination within its boundaries, is it possible to control the pollution of the stream at higher points?

This introduces the question, whether by suitable State legislation, riparian owners, whether individuals or communities, can be compelled to observe toward the City of Philadelphia the common obligation incident to similar rights as between individuals. The principle is well established which preserves to every person the use of running streams only so far as he does not impair their use and purity for others.

It is the opinion of your Board that the determination of the question of future supply should be entrusted to a Commission to be hereafter constituted, before whom should be laid the fullest information attained or attainable, together with such reports, plans, and projects, as may be submitted by the Water Department after the necessary data shall have been gathered.

REDUCTION OF WASTE.

Next to the importance of obtaining a proper supply of water comes the question of its economical use. Experience in other places has proved that the loss from leakage of service pipes and stop cocks, and from allowing waste of water in houses, factories, etc., is enormous, and effective means have been devised for discovering this loss.

Your Board consider it essential to an efficient conduct of the department that the Chief should be empowered to use all known means for finding and correcting this evil.

Another source of waste is the absence of proper methods of determining and valuing the use of water in factories and large public buildings. For these your Board consider that meters should be used at the discretion of the Department. It is impossible even to approximate to the amount of water used, on the basis of a given size of ferrule, because the quantities passing vary in different localities, according to the pressure, and because the use in some localities is more constant than in others. The only equitable mode of assessing in such cases is by the quantity actually consumed. This at the same time should check wastefulness. In most of the large cities the use of meters for large consumers has been found of great value. On the other hand, it is not desirable to affix meters to houses.

The first cost of these meters would have to be borne by the Department, but they might be made to earn a large interest on the investment, and would undoubtedly result in so considerable an increase of revenue in certain cases as to warrant a reduction in others, and the furnishing of water to houses at a cheaper rate than at present. At the same time it would be found that the consumption per capita would decrease, and with it, proportionally, the expense of the Department.

SUMMARY OF RECOMMENDATIONS.

1st. The application of the appropriation as specified for immediate needs.

2d. The acquisition of land for reservoirs at Cambria street and Mt. Airy.

3d. The organization of a surveying staff, with duties as indicated.

4th. The consideration of general legislation for protection of streams from pollution.

5th. Adoption of measures for the prevention of waste.

CONCLUSION.

In conclusion, the undersigned deem it proper to state that owing to the prolonged absence of their colleague, Mr. Chesbrough, caused by his illness, the responsibility thrown upon them has been greatly increased, and they deeply regret that they, as well as their fellow citizens, have been deprived of his valuable services during the latter portion of their labors.

Respectfully submitted,

J. Vaughan Merrick,
Fred. Graff,
William Ludlow,
Chief Engineer Water Department.

TECHNICAL TRAINING.

By Thomas M. Drown.

[An address delivered before the Alumni Association of Lehigh University, June 20, 1883.]

The part which the natural sciences of physics and chemistry play in our every-day life comprises about all that makes life practically worth living. A moment's reflection will convince one that to the physicist or engineer we owe all our methods of rapid communication and transportation, as well as the utilization and adaptation of power; and to the chemist we owe our supplies of metals and other necessaries of modern life. Technical schools have for their object the teaching of these sciences, with the direct purpose of their application to the well-being, the pleasure, the comfort, and the convenience of mankind. We will devote this hour to the inquiry how this object can be best attained.

Empiricism is the foundation of all art and manufacture. Nearly all the early discoveries in the arts were the result of accident or haphazard experiment. Useful results, which could be regularly reproduced, gave value to discovery and dignity to the discoverer.

It would be interesting—to take an illustrative instance—if we knew the circumstances connected with the discovery of metallic iron. We can well imagine that a fire, large and intense enough to reduce iron from its ore, must often have been made in accidental contact with surface ore, and that the presence of the metal in the ashes must have attracted attention. This observation once made, there would follow a series of experiments to determine the conditions under which the metal was produced, and the substances necessary for its production. It would not long escape intelligent observation that a certain red or brown earth, or may be a black rock, was the substance which yielded the metal, and that fire was the necessary condition of its formation. Then would, doubtless, follow many fruitless experiments with rocks and earths of similar appearance, until finally, the experimenters would learn to distinguish by the appearance, weight, color, etc., the deposits which contained iron from those which did not. But the iron thus accidentally produced—a mixture of metal, cinder, and ashes—was of no value until further experiment revealed the fact that the metal could, when hot, be united, by hammering, into one mass, with the separation of cinder and other extraneous matter. The discovery of this property of iron, as notable as that of its production from the ore, prompted still further experiment. The irregularity of the product would suggest the more perfect control of the fire, and small furnaces would be built with manifest advantage. Again, it would be found that ores from different localities behaved differently in the furnace or gave iron of different properties; and the best and most easily worked ores would be carried to distant furnaces, or the iron smelters would move to the vicinity of the best ores and build their furnaces there. In the course of time it would be noted that the iron was not uniform in hardness, and an accident would be sure to reveal the fact that sometimes the metal, when suddenly cooled in water, would become intensely hard. This new line of investigation would result in the more or less regular and controlled production of steel.

As the result of all this experiment certain favored regions would become celebrated for the manufacture of superior utensils and weapons of iron and steel, and certain men, more than usually intelligent or experienced, would become famous for their skill.

This was the school in which were trained the famous masters, who by work at the forge and anvil made themselves names which history passes down by the side of princes.

In museums of mediæval art we see specimens of smith's work which excite our wonder and admiration. These were made by the masters at the forge with intelligent, patient, and often loving labor. We see the sword which was carried and used by some warrior of old still fit for new conquests; we see the strong box, with cuning lock, in which some castle-robber kept his treasure; and we see the delicately-wrought screen of leaves and flowers, hammered from the soft and willing iron, which found its appropriate place in a cathedral.

In those days there were no technical schools, and, it may be asked whether, in such arts, we derive any practical benefit from school teaching. Is not rather the pupil's place at the master's side taking lessons, hammer in hand, while the master directs the blows? It may be safely answered that no system of class teaching, which modern experience or necessity has devised, can impart that subtle element of genius with which great minds, full of enthusiasm, inspire their loving pupils. Class teaching is a necessity in our day of general education, and the best that the teacher can do, in many cases, is to ignore individual differences, and to bring his pupils all to the same level in knowledge. It is a machine-like process that aims at a good, uniform product. The enthusiasm begot of the intimate relations of teacher and pupil must be subordinated to the general good of a larger number. The loss of this personal enthusiasm, while much to be deplored, is not without its compensations. The fact that say a hundred young men are taught where but one was taught before, not only multiplies the actual number of educated men but renders the evolution of great minds more probable. In the arts which are less capable of formulation the master system still survives. In painting and music there is a first, or mechanical, stage which can be learned from competent teachers in classes; but there is a stage beyond this, where the inspired master speaks a language which only the worthy pupil understands. Genius cannot be taught, but it may fall like the prophet's mantle on him whose gaze can follow his master into the celestial fire and see the forms of beauty and strength.

There is also in all the *practical* arts a region beyond formulas. It is in this region, shut out as by a cloud from the sight of the multitude, that the prophets live, spending their time in translating eternal truths into the language of men.

But, further, it is impossible to conceive of a school in the day of purely empirical knowledge. Art is appropriately taught in the shop; science, or classified knowledge, belongs in the school. It is nowadays rather the fashion to admire the works of the past, and to mourn over the degeneracy of modern art. It is true that the workmanship of old was often more thorough and complete than we find it in our day, not because the art was better understood, but because more time was taken to it. Time has increased in value, and it does not now pay to linger over the manufacture of a cabinet or table.

The mistake is often made of comparing the industrial arts of to-day with the fine arts of centuries past. Chairs, and tables, and carpets, and clocks belong to the necessary furniture of every-day life. Shall we mourn over the fact that they are now made simply and cheaply because we find that some of our ancestors lavished ornaments on their furniture, and studded their clocks with jewels? Does any one suppose the mass of the people of that day lived with these artistic surroundings? Fine art is not limited to paintings and sculpture, and in our day, we too, when time and wealth permit, refine our household goods into works of beauty.

There is a good deal of nonsense talked about "lost arts." There have been very few arts lost which were worth keeping. Disused arts are abundant enough, and may be revived if the demand arises. It is safe to say that the modern workman could imitate and improve upon any of the works of mediæval art in metal or wood if he thought it worth while. Do we not hear rumors of modern enterprise which can supply genuine antiquities fresh from the factory?

The mediæval workman, should he return to the scene of his earthly labor, would find himself unable to compete with the modern mechanic in his own art. His hand might retain its old cunning, and his soul be full of high purpose, but his forge and work-bench could not compete with the machine shop and saw mill.

The fine arts may rise and fall and rise again, but in the industrial arts there is steady progress.

How then have schools arisen? In the course of time as facts accumulated, and when it was found by the pupils who journeyed from one master to another, that the explanations of well-known facts were nearly as numerous as the masters, the necessity of classification arose to develop some order out of the tangle of facts. This is the period when schools appear, when men drop their tools to think over their work, and compare it with the work of others. The school is at the start an annex of the shop, having for its object the systematic arrangement of the facts which the shop supplies. But the school cannot long remain the patient handmaid of the shop. Facts developed by accident or experiment come too slowly to supply the mental machinery which has been put in motion, and the imagination supplies the facts which the mind demands—prophecies of discovery which experiment confirms or refutes. Now begins the era of intelligent investigation, and we have more than an industrial school which deals with the best practice, we have a school of science which seeks the causes of things. All technical schools go through this course of development—in engineering, chemistry, metallurgy, architecture, and even medicine, for it too is largely an experimental science.

The school, born of the shop, in time attempts to control its operations, and the inevitable conflict, so called, of theory and practice arises.

When sanitary science began to direct attention to the necessity of a better drainage system for houses, the workman in solder and pipes defiantly placed over his door the sign "Practical Plumber." Scientific agriculturists likewise developed the "practical farmer." There is scarcely a trade which has not taken alarm at the tendency of modern investigation, and many a craftsman fortifies himself against anticipated attacks in announcing himself; for instance, as a "practical hatter," a "practical cobbler," or a "practical bell-hanger."

Nor is it only in the trades that this reactionary tendency is noticed. Even in the professions which deal mainly with matters of mind or emotion we meet the suggestion of—the "practical lawyer," the "practical physician," the "practical politician," or even the "practical theologian." In matters of fine art too, it is often felt (but less often confessed) that the tendency is to expression beyond the comprehension of the layman, who would gladly welcome the revival of what he might call the "practical painter," or the "practial musician."

The phrase "conflict of theory and practice" is often used without definite meaning. Muscular labor is always conservative, and the conservatism is in direct proportion to the physical strength involved. He who works with heavy tools is more set in his ways than he who works with lighter ones. Manual dexterity is the transition from muscle to mind. Mental labor, on the other hand, is always radical, and is apt to forget the things behind in its striving for things ahead. The "conflict" is the inertia of labor opposing the restless advance of mind; it is in the nature of a check or brake which practice puts on the train of thought. Viewed in this light there can be no victory on either side, for both work together for the best result. Life would be the monotonous affair that Solomon found it "if the thing that hath been is that which shall be, and that which is done is that which shall be done;" but worse than this monotony would be the confusion, the chaos, that would result if theory proclaimed itself independent of practice. Human society has decided the former life to be merely dull, but for the latter it provides insane hospitals. The conservatism of labor is often mentioned with unjust reproach; we demand of labor, accuracy and uniformity, just as we do of machines, and we constantly endeavor to eliminate irregularities of product by division of labor, or by the construction of machines which do not get weary, do not go on sprees, or strikes. If, after this narrow training, we find that the human machine opposes the introduction of new ideas or processes, should we be surprised? We might as well complain that a horse-shoe machine would not adapt itself to make pins!

It is not unfrequently noticed that men who pride themselves on being "practical," are the most inveterate theorists; and equally droll is the quiet confidence that the schoolman often has in his ability to work in the shop or mill if he wanted to. It needs the personal contact of these two classes of men to develop mutual confidence and respect, with the elimination of ignorance. Happy is the man who combines in himself both the knowledge to think and to work.

We are very fortunate in this country in having a society in which the schoolman and craftsman, the engineer and the iron worker, the chemist and the furnace man, meet on common ground, without fear or jealousy, to learn from one another. No society in our day has made more real progress and done more good work than the American Institute of Mining Engineers. Its *Transactions* contain the record, side by side, of the best practice and the highest scholarship. This is the *fellowship* of theory and practice.

Technical schools are not indigenous in this country, they have been transplanted from Europe, and were originally formed on German models. The rapid development of our mines of the precious metals in the West, found us without the necessary technical skill to work them advantageously, and we were particularly deficient, two or three generations ago, in the knowledge necessary to work these ores profitably. German metallurgists came in large numbers to this country, and our young men were sent to German mining schools to fit themselves to take charge of mines and smelting works.

Many of us can well recall the young American returned to his native shore after a sojourn of two or three years abroad. He brought back with him an elaborate case of blow-pipe instruments, a collection of minerals and hammers, a well-assorted library, particularly rich in the German classics, an intimate knowledge of foreign social customs, a vocabulary liberally enriched in foreign technical terms, and a look and an air that seemed to say, "I am ready to show you how it is done." They had no difficulty in securing positions to put their knowledge to practical use, and while a few of them were successful, it must be confessed that many of these young men made lamentable failures at the start, causing loss to mine and mill owners, and bringing discredit on systematic instruction. We must also admit that the early graduates of our American mining schools were also often unsuccessful at first. There was evidently something wrong either in the works or in the school; and as a consequence, the school teaching of practical science sustained a serious check. The schools thought the works were jealous and put obstacles in the young men's way, and the shops thought the teaching of the schools impracticable, and unfitted the men for work. The trouble was simply that the young men had studied one side of the subject and attempted to practice the other. It was the case of an imperfect science attempting to instruct a well developed art. The case was complicated by the fact that the schools gave diplomas, asserting the graduates to be "civil engineers," "mining engineers," etc., and no wonder they thought the faculty knew best on this point.

Very often the trouble arose from the attempt to introduce foreign metallurgical methods into American practice, ignoring the fact that mining and smelting are primarily economic problems, and that the successful treatment of ores in one locality may be a failure in another. It is not in the least soothing to the capitalist, who discovers that his metallurgist uses more money to get the gold from the ore than it is worth, to be told that the process was scientifically correct and had been successfully used elsewhere.

Patience on one side and perseverance on the other brought about, at length, a better understanding, and the practical man recognized that the graduates of the technical schools were the best raw material for making promptly managers and superintendents. The school learning gave him an advantage at every stage of his work over the ordinary workman. This recognition reacted favorably on the schools, and the young men no longer thought their first duty was to instruct, but to apply their school knowledge. There is now no longer any distrust of the schools on the part of the works, in fact we may say that the schools have conquered the works, for the practical managers are now very generally the graduates of technical schools, and are very glad to get young men with technical training. They know just how to treat them and what kind of work to put them at. More than this: these managers begin to discriminate among the schools, finding some young men better trained than others, and there has thus arisen a beneficial rivalry among the schools to give young men the preparation best calculated to secure them places for work. Competition in schools is as healthy as competition in trade, and it is worth while to discuss the question what is the best course to pursue in teaching science as applied to the arts. Let us first try to define a technical school, or rather to determine its relations to other schools. We will begin negatively, and say.

1st. It is not a school of general culture. We must not attempt to crowd too many studies into a technical course. The student should, as far as possible, have in mind a clear outline of his course from the beginning. And yet no greater mistake was ever made than that which asserts that the engineer or chemist does not need to be liberally educated. In the year 1876 there was a discussion in Philadelphia, under the auspices of the American Society of Civil Engineers and the American Institute of Mining Engineers on the subject of Technical Education. It was called by the lamented Alex. L. Holley to consider mainly the question whether shop practice should precede, follow, or coincide with technical instruction. A considerable number of schoolmen, practical engineers, and metallurgists took part in the discussion, and nearly all of them insisted that the most important requirement of the engineer was culture. It is a narrow life that concerns itself solely with building bridges or making analyses. The best professional work is done by him whose life is spent in a gentle and cultured environment. It is deplorable to find a trained and competent engineer unable to write a report clearly and correctly. But what else can we expect when young men are sent to technical schools *instead* of to high schools and colleges? A professor in a Hungarian mining academy once said: "If there is any study in which you are particularly interested don't make your living by it; keep it for a hobby." This advice does not always hold good, but it contains the germ of a useful truth, that professional men should have interests of an elevated character outside of their daily work.

2d. It is not a scientific school, as this term is generally used; that is, a school in which the culture consists largely in the study of the natural sciences.

3d. It is not a school of pure or abstract science.

4th. It is not an industrial school in which the practice of an art is taught.

Technical schools are broadly distinguished from schools of general culture or science, by reason of special duty for a definite end, and are distinguished from schools of abstract science by the element of handwork which enters into them. From industrial schools they are distinguished by the element of experiment or investigation. Turning to the positive aspect of the subject we say,

1st. A technical school is primarily a place for the preparation of young men to earn their living in engineering, mining, chemistry, etc. Any system which overlooks this or makes it of secondary importance is faulty and unjust. Young men are sent to these schools with this end definitely in view. It is easy for any one to earn his living in mining or engineering with muscle and pick, but schools are established to fit him to make a better living with brain and pencil. It is the lighter equipment which does the most work and earns the most wages. A technical school can then be fairly judged by its results, namely, the character of its graduates. Are they the better or worse fitted for earning their living with their school learning than they would have been without? This is a fair test question. And yet most of the teaching in the schools is of a preliminary nature. Young graduates must begin at the bottom in practice, but in this position they are still generally able to earn something. Analytical chemistry is the only branch usually taught in the schools which is complete in itself and not necessarily preliminary to other work. The analytical chemist is, therefore, on graduation fitted to take an independent, responsible position. His work, after he leaves the school, does not differ in kind from that in the school. The same may be said in some degree of the department of physical testing, though this is less developed in the schools than analytical chemistry.

2d. A technical school is a device to save time. Man has always chafed under his limitations, and failing to discover an elixir which should indefinitely prolong youthful and vigorous life, he has directed his energies to making his allotted span fuller and richer. Man's days are still three-score years and ten, but he now crowds as much into them as Methuselah did into his nine hundred sixty and nine. It is generally considered good advice to youth that they emulate the career of noble, self-made men, who, beginning life poor, with no one to lend a helping hand, have struggled with fate and conquered, not merely acquiring wealth but knowledge. History is full of the names of such men, and the lesson they teach has only too often been interpreted to mean that success is conditioned on hardship, disappointment, and delay. But do these same self-made men thus read the lesson of their lives; do they advise young men to turn back and follow in their footsteps? Not so; rather do they say to young men, "I would not that you be spared thought, but I would save you from anxious thought; I would not that you be spared work, and even hardship, but I would save you from wearing uncertainty, and from that waste of precious time that my education has cost me; I would have you not go over the ground that I have gone over, but begin in youth where I leave off in age." Thus have acted, if they have not thus spoken, those great benefactors of our own valley—Asa Packer and Ario Pardee—in founding schools for technical education, that young men, without means, might not lose time in fitting themselves for useful work.

The will and the power to add a score of years to a useful life is benevolence almost divine.

3d. A technical school is a post-graduate school. In this respect it ranks with schools of law, theology and medicine. It is only in recent years that law and medical schools have taken a definite stand in regard to the proper preparation for these studies. Parents would choose between business, college, or a profession for their sons, and medical schools permitted men to matriculate without a question as to even a common school education. This condition of affairs is now fortunately passed—or is rapidly passing away—in the so-called learned professions, but it still exists to a great degree in technical schools. The reason is clear enough. These schools have grown out of the works and industrial schools, and their professional character is not yet fully recognized. Industrial schools train mechanics, technical schools train engineers. This distinction finds an apt parallel in training schools for nurses, and professional schools for physicians. We must not expect the public to discover and insist on this distinction; it must be made by the technical schools in setting their qualifications for admission.

4th. A technical school aims to teach the relation of abstract science to the practical arts. If we examine the catalogues of these schools we find a long list of subjects—mining, mechanical, and civil engineering, metallurgy, chemistry, physics, geology, mineralogy, drawing, mathematics, languages, etc.,—and to the list might well be added sanitary and electrical engineering. All of the studies have a direct bearing on human welfare. But the great number of them, with the ever widening scope of each, renders the arrangement of a course of study very difficult, and we not unfrequently find in a course a most heterogeneous collection of studies whose relation is merely superficial or one of sequence. Take for instance the course of mining engineering as taught in many schools. To obtain the degree of "mining engineer," the student must have a certain knowledge of geology and topography to locate ore-deposits, he must be a mineralogist to determine the occurring minerals, a mining engineer (in its narrower sense), to take out the ore, a chemist to assay it, a mechanical engineer to build the necessary machinery for hoisting and ore-dressing, and a metallurgist to extract the metal from the ore and work it into useful forms for the mechanic and civil engineer. To all this is often added a course in bookkeeping and mining law. It must indeed be a well-rounded man who has taken this all in.

A course of this kind is a survival of the time when all that was known on all these subjects taken together would not inordinately tax a youthful intellect; but as these subjects expanded, each into a science in itself, instructors neglected to divide the course into several independent courses and went on cramming the student to a point of unsafe tension.

Perhaps no classification that we could make of the branches taught in technical schools would meet the demands of all students, on account of the interlacing of the branches. At first sight we think we have a natural sequence in the subjects just named, that is, geology, mining engineering, mechanical engineering, metallurgy and civil engineering, and that we could divide this course into two or more courses by drawing lines anywhere between these studies. But this would make very artificial divisions. Mining engineering is not very different from civil engineering; the mathematical basis is the same in both and much of the work is the same. In fact, many of our best mining engineers have been educated as civil engineers, and have afterwards transferred their field of operations from the surface of the earth to its interior. It is not a very long step from the engineering of construction to the engineering of destruction.

Again, both the mining and civil engineer should know a good deal of mechanical engineering, which deals with the mechanisms for the utilization of power. The metallurgist is primarily a chemist, but the more he knows of mechanism and construction the better able is he to carry on his work. And so we might go on to show that the more a man knew of all these related branches the better he could perform his special work—an argument which would simply go to prove the advantage of omniscience. Unfortunate as it is in many respects we must be reconciled to the necessity of becoming specialists, and to call in other specialists to help us. Perhaps the most we can hope for is to be an expert in one department and to know enough of the related departments to judge of the harmony and fitness of the combined work of many heads and hands.

In a general way we may divide technical studies into engineering and metallurgy, but a broader and better division would be into physics and chemistry; under the former subject being arranged those studies which have a mathematical basis, and under the latter metallurgy and other chemical branches.

At the risk of overthrowing both classifications it must be mentioned that a most useful combination course is one in metallurgy, which ignoring all engineering branches, deals with the chemical and physical properties of metals and alloys. This is the great virgin field in technology which promises a grand harvest of valuable results to him who works it patiently and intelligently. The civil engineer does well to complain that the ignorance of the metallurgist with regard to the properties of the metals used in construction hinders his progress and introduces great uncertainty into his work.

To the question what should be the method of teaching, I would say,

1st. Negatively—nothing should be taught in the schools which can be better taught in the field or shop. While this broad proposition must meet with general acceptance, there is yet a great diversity of opinion where the line should be drawn between shop and school, or just how much shop belongs in the school, or how much school belongs in the shop. It is not my purpose to enter into this discussion at present, but it will be admitted by all that,

2d. The school rather than the shop is the place for finer research and experiment.

3d. The subjects taught in the schools being largely experimental, and consequently belonging to the growing and advancing sciences, it should be the object of the teacher not only to give the student the present condition of the science, but to identify him with its growth.

As to detailed methods of teaching, it is not well to enter too minutely, for this is a matter for the individual instructor, who will have, if he is in earnest, his own methods based on his own experience or his own theories. This personal element we cannot eliminate, if we would. And yet there may much good come from the discussion by teachers of their methods and results.

Teaching involves three processes—*instruction*, or the imparting of information; *education*, or the development of the mental faculties; and *training*, or the formation of habits of thought and work. Good teaching, whether in kindergarten, college, or professional school, is the happy combination of these three processes. In childhood, the element of instruction predominates; in colleges, education; and in professional schools, training; but no one of these elements can be absent in any kind of school without an imperfect result. In technical schools there is a good deal of general information which must be acquired, and a good deal that must be memorized, there is no escaping it. There is a certain amount of preliminary work which must be done, once for all, without which no sure progress can be made. There are no short cuts to knowledge at this stage. In education, the instructor's work assumes greater delicacy; it should be full of suggestiveness and guidance to develop the reasoning faculties and guard against their inaccurate or desultory action. Training, or the formation of habits, is a very different process, and one, the importance of which is not, I think, fully appreciated. The frequent repetition of any action not only enables one to do it easily but also to do it automatically. Muscular action is largely automatic. When one slips he throws out his arms to keep himself from falling; this is not instinct, it is habit. If he had to consider every time he lost his balance how he should restore the centre of gravity within the base, he would have many a fall which he now avoids. We admire the accuracy and precision with which a blacksmith wields a sledge, or the dexterity of hand of the accomplished musician which transmutes the printed page into melody, or the prompt and graceful evolutions of soldiers at the word of command:—all this muscular exertion is done with scarcely any expenditure of nerve force.

The mind, too, can be trained to think and act in defined channels with great saving of power. Consider for a moment, how specially trained men look upon any object or incident. A jewel may be simply a thing of beauty to the ordinary observer, but to the mineralogist it is a crystal having a certain color, hardness, specific gravity, etc. So does a botanist classify a flower, or a geologist a fossil. In like manner in the recital of an incident, say a railroad accident; an engineer will at once think of the cause, a physician of the injured, a lawyer of the damages. These thoughts arise automatically, and are the results of training. The saving of vital energy which this training effects is one of the great economies of life.

The process of growing old consists in the ossification of thought and action into habit. It is obviously the duty of a teacher to have an oversight over the mental habits that his pupils are forming. A fact or a law mislearned can be corrected without much harm being done, but slovenly habits of thought, the substitution of guessing for proving, incomplete experimenting with the multiplication of factors of ignorance—these are practices which, when confirmed into habits, can with difficulty be eradicated.

Morally, habit is a very good practical substitute for purpose, and it may be said, in passing, that moral teachers too often overlook the good that could be accomplished in training in right thinking and acting. It is not an altogether utopian notion that one, for instance, could form the habit of telling the truth, which would serve him in good stead and save his moral nature from many an embarrassment.

If I mistake not, the principal work of a technical school should be the training of young men in accurate habits of thinking and working. Without this training the graduate is slow to adapt himself to new situations. The student who has been put through a routine course of study, abounding in the use of text-books and in the solving of many problems, may be fairly informed as to the condition of his profession and may have acquired good habits of study, and yet be unfit for practical work which involves principles which he has not learned. The proper training cannot be given in the class room, but must be obtained in laboratories.

And this is the thought to which I wish to give prominence: that the centre around which should cluster all the teaching of a technical school should be physical and chemical laboratories, and that the ruling idea of the school should be experiment and research. The time has now fully come for technical schools to take this advanced position in the scientific training of engineers and metallurgists.

The development of the school out of the shop has been so gradual that it is somewhat difficult to realize that the differentiation is now complete, and that the methods which are adapted for industrial schools do not fit the professional school. There are those who regret the widening of the gap between head-work and hand-work, but this regret comes from a misunderstanding of the situation. Technical schools are not intended to teach a young man to puddle iron, to lay rails, or clean castings,—useful work, indeed, which he can readily learn before he enters the school or after he leaves it. We should not declare his education imperfect or worthless because he cannot handle a rabble or chisel.

A great difficulty in teaching a growing science is that what is taught to-day may be obsolete to-morrow. One who has spent four or five years in a technical school will realize this when he gets into actual practice. Ought there not, therefore, to be a system of teaching which shall recognize this growth and be adapted to it? To this it may be objected that the worst possible preparation for actual work would be to give the student the notion of the general instability of things, and that he must be on the look-out for the latest novelties in his profession. But we need not render unstable the attitude of a student by showing him that the ground on which he stands moves, and that he will be left behind if he does not move with it.

It has been said (to change the metaphor) that a teacher should be abreast of the current of thought in his profession. The figure is fortunately chosen in that it enables us to point out a grave mistake. He should not be abreast of the current, he should be in it, irresistibly borne on its surface and adding by his weight to its momentum. It is the introduction of the student into this current that should form the principal work of the teacher. The majority of students and workers never get into it. This may be the fault of the teacher, or it may be that the student is timid and prefers to keep up with the current by running along its borders. A few succeed in the attempt, but the majority give up the tiresome race and stand and see the stream go by. The figure illustrates the process of acquiring knowledge from books or practice alone—a process not without value to those whose imaginative and questioning faculties are undeveloped, and who prefer to take their facts at second-hand. But no teacher should be satisfied to let a student take this stand until he is convinced that he has not the ability and aptitude for original work. The life of the collector is a narrower one than that of the discoverer, and the teacher's duty is to show the more excellent way.

What process of teaching will put the student into synchronous motion with the science that he is studying? Again, I reply, the training of experimental laboratories. This training cannot begin too soon, it cannot last too long. No special preparation is needed for it other than a little preliminary practice in the use of apparatus and methods. The student should live in the atmosphere of investigation. There should be no separation of beginners, advanced pupils and professors, but all should work together as far as possible. No teacher is primarily interested in teaching who does not like to have students about him when he is experimenting. By this association of workers there is a manifold advantage, for each one can follow in a general way the work of his neighbors and profit likewise by their experience.

The student should feel as soon he enters a technical school that it is a laboratory of research and that he is one of the workers. Much patient plodding is yet before him in studying text-books and showing he understands what he has learned by recitation; but his study is no longer drudgery, for he sees immediately its application. I often wonder at the patience of youth who devote years of their life to school-room work with quiet faith that their studies will sometime have practical use, and who cherish perhaps a furtive hope that they may live to discover a new and interesting fact. I wonder, too, at teachers who think that a student must not too soon get a notion of his own powers lest he should become unmanageable through over-confidence. What would we think of a system of studying botany which shut up the student for years within four walls where he could not see a green thing, and supplied him only with dry specimens and pictures of flowers and trees, for fear that a glimpse of nature's wealth of growing forms might lead him away from their systematic study? The comparison is scarcely overdrawn. In many schools chemical laboratory-work is regarded as a preliminary practice for useful work hereafter. A certain number of substances—simple salts, mixtures more or less complicated, rocks and minerals are given to the student to work on, and his only interest is to get the correct result, as a boy ciphers his sum towards the answer given in the book. Such work is depressing and of the nature of a task, and it is scarcely a matter of surprise to find, in cases where there is an unsuspicious teacher, that the work is slighted and the results taken directly from a key which the students of one class thoughtfully pass down to their successors. The proposition to give to the beginner some interest in his work, in the nature of an original investigation, which would yield results having value in themselves, is one, I fear, which the ordinary student would receive with surprise, and one which many a teacher would consider a sure method of leading a student away from the sober studies he came to school to pursue. Those who thus reason don't understand the proposition, or they have never tried the experiment. It is not proposed that a student should neglect to acquaint himself with the fundamental principles of the science he is studying in his endeavor to get new facts. No more harmful suggestion could be made than this, that the object of one's studies is principally to discover something. There are plenty of people doing just this thing—shiftless, unprofitable workers, always on the verge of a great discovery which is to revolutionize things generally.

In the system proposed the development of this class of discoverers is impossible. No one knows the value of a fact like him who has secured one for himself—isolated it, weighed it, measured it; and no one knows and feels the harmony, and beauty, and power in a law like him who has collected many facts and seen them crystallize into transparent truth. No one is less likely to be led into error than he who has been trained to prove all things and to hold fast that which is true.

The notion has considerable prevalence that discoveries in physical science come in the nature of revelations, through specially inspired channels. I doubt if many students of engineering and chemistry look forward to a career of investigation and discovery, unless they should have a kind of "call" to the work. And yet if we go into any chemist's or physicist's laboratory we can hear of thousands of unsolved problems which are merely waiting for patient, thoughtful, trained workers.

It should be the chief object of the technical school to give this training. It belongs in the school and can be better given there than elsewhere. The probability that a student will ever have the opportunity to get this training after he leaves the school is very small. Practice he will get enough of, but the ability thoroughly to investigate statements and processes does not come with the daily practice of an art. It is not merely the skilled hand and quick eye that is needed, it is the trained mind which not only gets at the truth but shakes off error.

This process is often spoken of, figuratively, as questioning nature, who always replies promptly and clearly and without hesitation or reserve. How is it then that so many of her answers appear enigmatical and confusing? Simply because the question is not properly put. To continue the figure—investigation may be called the art of putting questions; and this art very few people possess even though they may be endowed with a prying inquisitiveness. Nature is not a gossip, does not speak until spoken to, does not tell more than is asked of her. But it is a process, I insist, that can be taught, and it is much better that one should learn it properly than depend on the chance of picking it up. Things which are picked up are generally imperfect or rusty.

While the object of the method we are advocating for technical schools is not primarily the discovery of facts, but rather the training which this method of investigation gives, yet it will be admitted that a large part of modern engineering or metallurgical practice is based on facts discovered in physical and chemical laboratories.

Let us look for a moment at that greatest of all modern inventions —the Bessemer process—an invention which has made travel safer and more rapid, and cheapened all the necessaries of life. There never was a great discovery which was made known by its author in a more perfect and complete form than this; and yet for some time after it was in successful use very little was known of the chemical nature of the process. But the chemists were soon busily engaged with it, and the work which has been devoted to the explanation of the process the world over would fill many a ponderous volume.

Without this work the process would have made but slow progress, for unguided experiment would have been long in discovering what irons could be used and what irons could not. Chemical analysis soon was able to prescribe a formula for the pig iron adapted to the process and to predict just how each iron would behave. So completely is the process now understood that the softest iron and the hardest steel can be made by it at will. But the chemists did not stop here. Phosphorus was the element which had given the most annoyance in the process, and for a time it seemed definitely proved that only the pure ores—those free or almost free from phosphorus—could ever be used in the process. But the chemist is fertile in resources and a tireless worker, and to-day we have a variation of the Bessemer process, which ranks as a new industry, and the corner-stone of the process is phosphorus. I know of no more interesting chapter in iron metallurgy than that which traces the development of this "basic process," or one which better illustrates the value of chemical investigation in industrial operations. This is but one instance. Chemical analysis is now indispensable in all metallurgical operations, and, in fact, the chemist's work is at the foundation of all trade and commerce.

The physical laboratory should command our attention equally with the chemical. Here is studied the relation of the molecular structure of metals to strains, heat, electricity, etc., and when the results obtained in the physical laboratory are correlated with those from the chemical laboratory we have the necessary data to guide us in the preparation of the metals. There is no doubt that the time will come, and many of us will live to see it, when iron and steel will be made on a formula like a physician's prescription. We are not quite ready for it yet, for there are too many unknown quantities entering into the problem. When the schools establish laboratories for research the necessary facts will soon be forthcoming, and our amazement will be great that we groped so long in the dark when the light was so near at hand.

The physical work on iron and steel which has been done in the present generation is enormous, and much of it has been work which could have been done in the physical laboratories of technical schools. Recall the knowledge we now have of the properties of hard and soft steel, of the effect of punching, hammering, and other mechanical treatment, of the fatigue and wear of metals, and of their adaptation to special uses.

We might talk by the hour of the subjects which could be advantageously and appropriately investigated in the school laboratories, in electricity, pneumatics, hydraulics, etc., but enough has been said to indicate that laboratory research lies at the basis of all progress in the arts.

To resume. The ideal technical school is one which is entirely distinct from the industrial school and is thoroughly professional in its character. Qualification for admission should be a preliminary course in college or scientific school, or its equivalent, and the student should at once begin work in the laboratories. His work should have the double object of giving him practice in manipulation and an insight into the methods of research. He should be interested in the results obtained, which he should regard as positive contributions to accurate knowledge, even though they should be negative with respect to the particular investigation.

I know of no work of a teacher which requires more delicacy, firmness, and sympathy than guiding a student in work of this kind. Class teaching is here out of the question, and the pupil must get his inspiration directly from the master. He may have to encourage by practical help those who are disappointed in the results of their work or who grow weary in waiting. He may have to discourage those who are over-confident and hasty in anticipating results by allowing them to go astray until they find themselves hopelessly involved in difficulties. He must watch carefully the mental attitude of the student to find out whether he is striving to prove a theory or whether he is simply desirous of discovering the truth. It is a grand work for one who is fitted for it and whose life is given to it. No teacher in other departments sees so quickly the result of his training or is so sure of his reward.

The desire of many teachers to bring their pupils to their own standard induces them to lead the students over the ground which they themselves have gone. This is clearly a faulty method. A wise instructor will take a student quickly through the past so as to enable him to understand the present, but he will not let the student linger too long. We would not undervalue the work of the historian, but we would not have this work supersede the process of making history. The collection of knowledge and its systematic arrangement is valuable work, but it must soon come to an end if knowledge does not increase.

Technical schools should also offer opportunity for their graduates to continue their work. Fellowships should be founded to encourage graduates to remain in the school and aid in the work of instruction, for the system advocated necessitates a large number of teachers and overseers. Provisions should also be made for the temporary accommodation of experts who wish to make special investigations. Busy practitioners are seldom able to have well-appointed laboratories of their own, and would rejoice if the chance were offered them of working in those of the school.

Will it be said that this scheme savors more of a school of pure science than of science applied to the arts? Far from it; it is intended to be intensely practical. It is impossible to draw any sharp line between pure and applied science, for the science which is abstract to-day may be embodied in a patent to-morrow. Modern electrical practice had its rise in Franklin's kite-flying and Galvani's diversions with frogs. The methods of experimentation are the same in both, but a wise teacher will confine a student's work to those subjects which have an obvious bearing on the practical arts.

The ignorance of the graduates of technical schools of the simplest practical procedures in industrial works has often exposed them to ridicule, and many schools, in consequence, have added work-shops and furnaces and engines to their equipment to give the students a general idea of machines and tools before sending them forth to work. This combined course of study and practice has earnest advocates among those who have tried it. And yet these school-shops and school-furnaces would never, I think, have been built if it had been understood at the start that the graduate did not pretend to know anything about the routine of the shop, and that he expected to learn his trade like any one else. Playing practice is not only useless—it is hurtful. If the student enters the works with mere book knowledge he spends considerable time in trying to see the bearing of his studies on the practice of the art. If left to his own resources it is about an even chance whether he succeeds in this attempt or gets discouraged with practice (and perhaps takes up teaching), or throws aside his books and regrets the time he spent over them. The saying that one must *un*learn, when he begins to work, all that he learned in the schools has done much harm, but there are not a few practical illustrations of the saying. One might as well say that arithmetic was all very well in a school, but for good, square, accurate calculation a man had better confine himself to counting on his fingers or notching a stick. He who begins work with some preliminary training in the school-shop has, it is true, a better start, and there is perhaps less likelihood of his being discouraged by unfamiliar surroundings.

Very different is it with him who enters the mill or machine-shop after a long experience in physical and chemical research. His trained mind and senses detect relations and incongruities of which another would not be conscious. He has already learned to trust his own observation and judgment and to know their limitations. If a process is imperfect he quickly decides in what direction investigation is needed; he loses no time in fruitless experiment; he knows when he has enough facts to form a theory of causation and when he has enough to determine definitely the cause. He is not misled by apparent economies; he is not satisfied until he knows the precise efficiency of a machine; he gives "undetermined elements" no chance to play important roles, for he convinces himself of their presence or absence. Far from this training in investigation making him an impracticable theorist, he is fairly hungry for facts. It makes little difference to him whether or not he ever handled a steam engine in the school or worked at a lathe; this is experience which he can quickly gain if his inclination or duty calls him to this work.

This advanced position which we would give to technical schools may render it desirable that the industrial or shop-schools should be multiplied. At all events, it is well to maintain that there are schools —call them by which name you will—which give the higher professional training in practical science as distinguished from shop-training. Let him who will fit himself for a master mechanic get his training in the industrial or shop-school, and him who wishes to be an engineer get his training in a technical or professional school, but let neither one complain that he did not get in one school the kind of training peculiar to the other. Fortunate is the man who has the time and means and desire to go through both these schools.

The equipment of a school of research will naturally consist mainly in apparatus designed for special investigation. There will be, of course, the usual apparatus for accurate measuring and weighing in the routine processes of physics and chemistry, but there will constantly arise the necessity for the construction of special apparatus, and this is in itself a great assistance in the training of students, who not unfrequently get the idea that the bright apparatus which fills the cases of college collections are the working tools or machines of the physicist, when they are merely his apparatus of illustration.

An investigating mind never grows old. We speak often of old-fashioned engineers, men not "up to the times," men who distrust modern ideas and hold to the methods of a past generation. These men were "up to the times" once, but because they simply learned the practice of their day and failed to catch the spirit of its growth, have been left behind as practice advanced. There is no danger that the student trained in research will ever get "behind the times." It should not be the aim of any teaching to put old heads on young shoulders, but rather to keep young the heads which rest on old shoulders.

We can well understand the anxiety of the painstaking teacher who wishes to give his pupils as large an outfit of useful facts as possible; and yet if we reflect on the immense accumulation of facts in practical science, what does it matter whether the student gets a few more or less when the time of acquiring these facts might be devoted to learning the methods by which these facts were discovered? It would be poor policy to devote time to the practice of forging nails one by one, instead of becoming familiar with a machine which makes them by thousands.

It cannot fairly be said that the development of technical schools into schools of research would remove them farther from practice of the arts which they were instituted to foster. It is true there has been a break between the works and the school, but the gap has widened only to be narrowed again in the formation of a new and closer union. To make this union more complete the schools should be prepared to undertake practical investigations for the works. It is fitting that the schools should undertake such investigation for the professors are trained to the work and devote their lives to it. Many of the experiments made at works are imperfect, incomplete, or even inaccurate, because the person in charge of them does not know how to go about this kind of work, or is busy with other things.

The condition under which the school should undertake investigations for the works are:

1st. The subject should give fair promise of developing new and valuable information.

2d. This information, when obtained, should be published by the school.

3d. There should be no charge for the service.

If the schools did reliable work there would be no lack of material for investigation, and it would not be long before the supposed benefit derived from business secrets would disappear in the general diffusion of information.

Spontaneous evolution develops both useful and worthless variations; natural selection determines the survival of the fittest of them. Evolution by design, limits the production of useless forms and is thus more economical of power and time. Empirical development in the arts may aptly be compared with spontaneous evolution, while scientific research controls and guides the development. The technical school should be a centre of evolution by design.

Engineers have in late years implored Congress on behalf of science, on behalf of the welfare of fifty millions of people, to establish a board for testing, on a large scale, iron, and steel, and other materials of construction, that our buildings may be more secure, our bridges safer, and our boilers less liable to explode. After a brief and useful career the first United States Board expired, and no favorable legislation has been obtained to revive it. The general arguments urged in favor of the government undertaking this work, are that the outlay necessary would be more than most individuals or corporations could afford, and that business interests would prevent a combination of manufacturers for the sake of so beneficent an object.

Is it too much to expect that some friend of the higher technical training will be found to endow a testing department in a technical school? This is the proper place for accurate experiment, for here we have the men trained to the work. Removed from all the disturbing elements of trade, from the influence of politics, and from the jealousies of engineers, the testing department of a technical school could, by reason of its permanence and independence, do work which would find universal acceptance. I think the suggestion worth the consideration of the Alumni of Lehigh University.

I have sketched what I regard an ideal technical school. But the sketch is only the embodiment of tendencies plainly to be observed in our most advanced schools. The course which Lehigh University has always pursued in maintaining a high standard of scholarship, the work of research of her instructors and students, the increase in her great library and the extension of her laboratories, indicate that she is advancing steadily and surely towards the realization of this idea—that technical schools should be an assemblage of workers in experimental science.

What, it may well be asked, is the meaning, and what is to be the result of all this restless activity in the arts? The mechanical engineer studies the phenomena of combustion, the properties of vapors, and makes his mechanism more sensitive and accurate that less coal may be used to drive his machinery. He is saving power. The chemist works on the crude ores and rocks, and on vegetable and animal products, to extract as completely as possible the substances useful to man. He is saving material. The engineer makes the rough places smooth, hews paths in the solid rock, and hangs road-ways in the air. He is saving time. Where does man learn this lesson of economy? Nature appears to him as a spendthrift, counting material by worlds, prodigal of unlimited power, and reckoning time as a moment bounded by eternities. Why does man spare and store? Is he better or happier for it? Suffice it, in answer, to say that he obeys an instinct of his nature as irresistible as that of self-preservation. It is, in fact, for his own protection that he accumulates wealth in its various forms of substance, power, and time. We may not sit in judgment on this instinct and call it selfish,—it is for the *use* of his wealth that man must give account.

But we surely cannot fail to recognize the progress that man has made in the beneficent use of power. Are there not evidences on every side that many find greater pleasure in the unselfish use of wealth than in its acquisition, and are we not justified in expecting a time when man shall use his power only for good?

But is this restless activity never to cease? Are we progressing towards a millennium when the very earth shall tremble with the workers in its mines, when its surface shall be a tracery of rails and wires, when the roar and clatter of machinery shall deafen the ear and the smoke of countless chimneys obscure the light of the sun? Is there never to be rest from toil? It is a short and imperfect vision that thus divines the future. Each form of power advances to its own extinction in giving birth to subtler forms of power. Each mechanism is in time abandoned to give place to more effective machines.

Would you realize what power man has grasped, go to the forge and watch him as he, single-handed, directs the mighty hammer which, as if half ashamed of its great strength, coaxes the yielding iron into shape!

It scarcely needs illustration to prove that the tendency of material progress is toward the replacing of the mediate by immediate use of power. Perhaps few of the toilers recognize this tendency, but the more thoughtful and far-seeing look ahead to the promised day when, "if man shall say to the mountain, 'Be thou removed and be thou cast into the sea,' it shall be done."

This kind of faith and power, we are told, cometh only with patient, self-sacrificing seeking. It is a favorite figure which represents man wresting from nature her secrets and treasures by dint of persistence and prowess. Nature is never conquered by defiance; she surrenders only to those who first surrender to her. It is the victory of obedience which man gains over nature, and it is the patient seeker after the truths which she carefully guards who is rewarded by her bounty and whose commands she obeys.

We smile as we read of the conquering hero of old, who, elated with his victories over man, commanded the waters of the sea to obey him. And yet we say to the lightning, "take thou my message and carry it to yon distant city;" and scarce have we uttered our command when we hear the voice of the fleet messenger—"thy servant brings thee answer."

The tendency of both material and spiritual progress may be summed up in the one word *knowledge*, for it is only perfect knowledge that renders perfect goodness possible. Is there a nobler career for a young man to select than one devoted to the discovery of nature's laws, and their application to the good and happiness of man? And is not this the life of the miner, who puts nature's reserved wealth into circulation; and that of the chemist, whose touch transmutes into value the dust of the earth; and that of the engineer, who, in annihilating space, makes one all nations of the earth?

It is well for us at times to take our thoughts from our own special and partial work to contemplate a broader horizon which includes with our work the work of others, and to see the harmony which arises from the fitting of related truths. Sometimes we think we get a glimpse in this harmony of a part of a great design, which makes our souls long for the time when in the perfect knowledge of God's laws, we shall have a revelation of His purpose.

Radiation of Silver at the moment of solidifying.—At the International Electrical Congress, in 1881, J. Violle proposed as an absolute photometric standard the radiation of a square centimetre of melted platinum. Dumas approved of the proposal, and at his invitation Violle performed some preliminary experiments with silver. From the moment when solidification begins, in contact with the containing vessel, until the whole becomes solidified, the radiation of the liquid part remains constant. The constant portion of the radiation is so sharply defined that silver may furnish a secondary fixed standard, which will be especially convenient in all the measurements of spectrophotometry.—*Comptes Rendus*, April 9, 1883. C.

MINING AND STORING ICE.

By W. P. Blake, F.G.S., New Haven, Conn.

[Read at the Boston Meeting of the American Institute of Mining Engineers, Feb., 1883.

We are so familiar with water in its liquid and its solid form, that we seldom think of it as a mineral, and still less as a mineral product of any considerable industrial importance, which in the form of ice is mined and stored up in enormous quantities yearly. The industry is peculiarly American, and in no other country has the business of cutting and storing ice been so well systematized and perfected. The interest has grown steadily from year to year, until it has attained large proportions, the annual production being counted in millions of tons, requiring in the aggregate, a large investment of capital in all the Northern States. It gives employment, also, to thousands of men and horses, in the depth of winter, when farming work cannot be carried on. Ice is not only a luxury, but a necessity, in our climate, and is indispensable in many manufacturing operations, and finds constantly increasing applications and uses. As the industry has grown, so the necessity for suitable implements and tools has grown with it, and it has become necessary to systematize and cheapen the methods of handling such a large amount of material with rapidity and economy.

As the industry is properly a branch of *mining,* and as our mining literature does not, to my knowledge, contain any description of the methods and appliances used in it, it seems desirable to place a brief description on record in our *Transactions,* I therefore offer to the Institute the following outline description, based partly upon observations for several years past of the methods and processes employed, and partly upon the information obtained from prominent ice-miners and from the manufacturers of ice-tools. My acknowledgments are particularly due to the firm of W. T. Wood & Co., of Arlington, Massachusetts, for much information in detail, and also to the Knickerbocker Ice Company, of Philadelphia. The wood-cut blocks used in the illustration of this paper, have been kindly lent by both of these firms.

The sequence of operations in getting ice is as follows:

1. Wetting down a light snow.
2. Scraping off an excess of snow, if present.

3. Marking out the field.
4. Ploughing and cross-ploughing.
5. Cutting the channel and detaching large floes.
6. Floating the floes to the channel.
7. Splitting off long strips of blocks.
8. Floating them to the foot of the elevator.
9. Dividing into single blocks.
10. Elevating the blocks.
11. Receiving the blocks at different platforms and sliding them into the houses.
12. Storing the blocks in regular tiers in the ice-houses.

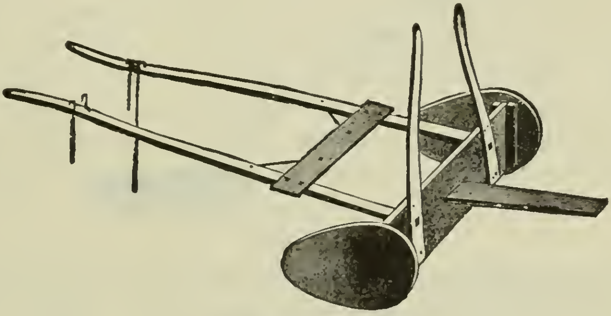
PREPARATION OF THE FIELD.

To insure perfectly clean and pure ice, pure, clean water is the first essential. Next, it is important that all dust and dirt shall be kept from the surface of the ice while it is forming and during harvesting. These conditions are best secured by a mantle of snow over the country which prevents dust from being swept upon the ice by the winds from adjoining roads and fields. But snow upon the ice is undesirable, although when the winter is open and ice does not form of sufficient thickness for economical harvesting a covering of snow may be utilized by flooding or "wetting down," as it is termed, so as to gain a greater thickness of ice. This flooding is accomplished by a number of men with ice-chisels, who traverse the ice-field in parallel lines about six feet apart, and punch holes through the ice at intervals of six feet as they advance. The weight of the men causes the ice to bend downwards, and the water rising through the holes penetrates and is gradually absorbed by the snow. The action is slow, and the snow is reduced in bulk to one-third or even one-quarter of its thickness when dry. The same operation is sometimes executed, not to gain an increased thickness for harvesting, but because the ice may be too thin to permit the horses to be used upon it; and often because an inch or two of snow ice is regarded as an advantage in protecting the clear ice below it from thaws before a good thickness for cutting is reached, and also because it makes the cakes of ice tougher and less liable to breakage in handling. But a full thickness of clear ice—from twelve to fifteen inches—and without a heavy covering of snow is the most desirable form in which the ice can be had. This, however, is rare.

Probably such a favorable state of the ice is not realized oftener than once in ten or twelve years.

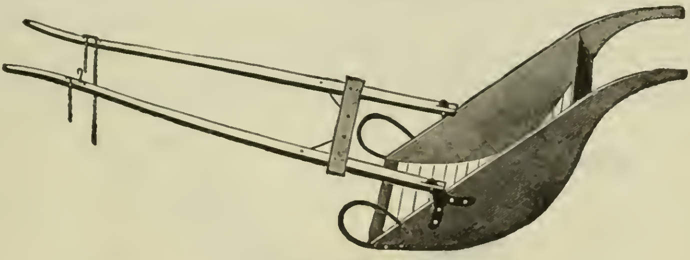
After the first light snow is wet down, and before the ice has fully grown to the desired thickness, other snows may accumulate, and must be removed before the operation of marking out and cutting commences.

Light dry snow is scraped off by means of scrapers or scoops, which vary in construction in different places, but are arranged to be drawn by horses. A common form of clearing-off scraper six feet long, is shown by the annexed figure.



Clearing-off scraper.

Heavy snow requires a scraper formed like a scoop, so that the snow may be moved in it to a considerable distance. The scoop-scraper is generally three feet wide and is fitted with an iron or steel-edge plate. It is shaped as shown in the figure, and besides the ordinary use for cleaning off heavy snow it is used to take away the wind-rows of snow left by the clearing-off scraper. On small ponds it is necessary to dump the snow on the shores, but on large lakes and rivers where there is an abundance of room the snow is dumped at one side out of the way.

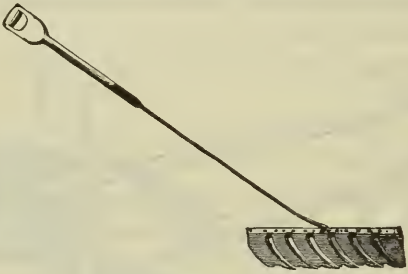


Scoop-scraper.

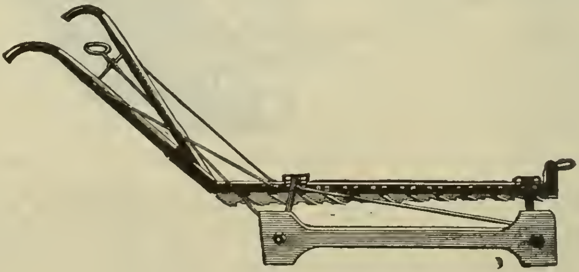
MARKING OUT THE ICE.

The ice being cleared of snow the next operation is marking out of the field, preparatory to cutting.

There are various ways of striking the first line. Some stretch a line between two pins set, say 200 feet apart, and then follow this line by a "marker" carefully guided by the hand so as to preserve a straight line. Others use a straight edge of plank fitted with sights, and this is the best method. Two stakes are first set up in the desired direction of the first cutting and at the side of the field. These may be set 500 or 600 feet asunder. The plank is then brought into line between the stakes, by means of the sights set in each end. A hand plow is then run close to the edge of the plank from end to end, following it as a ruler is followed by a pen or a knife. When a straight groove is cut about half an inch deep, the plank is moved one length ahead and is again brought into line by the sight, and so on the operation is repeated until the full length of the line is marked out by a straight groove in the ice. This is the initial or base-line of the cutting, and it is followed by a tool called a "marker" provided with a swinging guide. The teeth of the marker are placed in the shallow



Hand-plow.



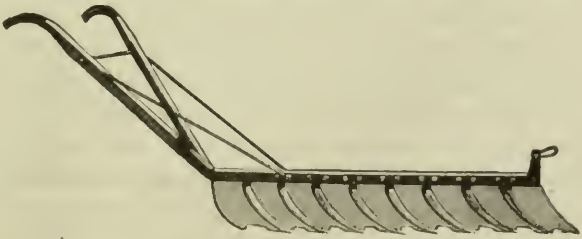
Marker, with swing guide.

groove and run across the field, deepening the groove to three inches and leaving it $\frac{7}{16}$ths wide. During the progress of this first cut, the guide is either taken off or is allowed to slide alongside on the smooth ice with the handle thrown out of the retaining-notch, the tool being guided by the eye and hand of the operator, aided by the groove. In this manner one straight groove three inches deep is made across the field at one side. The guide is then brought into use and is swung over the back of the marker and takes its place in the groove. The distance between the guide and the teeth of the marker is generally 22 inches. The tool is then drawn back across the field and a second groove is cut parallel to the first and 22 inches distant. This operation is repeated until the desired width of field has been traversed and marked by the parallel grooves. Although 22 inches square is a common size of ice-cakes, shippers of ice usually cut their ice 44 inches square and house it in this form, cutting it up afterwards into 22-inch cakes in the summer. When this large size is required, the guide is set 44 inches from the marker, and the field is then marked off in half the time required for 22-inch marking.*

The cross-grooves are next cut in a similar manner. Care must be taken to secure a right-angled intersection of the front cross-groove with the others. This result is usually secured by a large wooden square, placed on the ice with one edge laid along the first groove, while sighting along the other edge to get the position of the stake. A better method would be to use a line and strike two curves as in draughting, so as to strike a perpendicular. With two marking tools the two systems of lines can be run simultaneously, and much time may be gained.

PLOUGHING THE GROOVES.

The next tool brought into use is the ice-plow, by which the grooves



8-inch plow—8 teeth.

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* For further observation on the size of the blocks, see *infra* pp. 365–366.

made by the markers are cut to the required depth, generally to about two-thirds the total thickness of the ice.

The ice-plow is a very important instrument and has finally reached a highly perfected form, as the result of many years of experience and effort. Its invention and first manufacture dates back as early as about the year 1839, and it has now generally superseded the use of the saw and the axe for cutting ice.

The form and construction are indicated by the figure. It consists of a succession of curved, blade-like teeth, attached to a long beam with interspaces in the teeth for the escape of the ice chips. These teeth are now so formed as to clear themselves and carry the chips neatly out of the groove with little resistance. In noting the progressive improvement of ice-plows, I cannot do better than to quote from the description given by Messrs. W. T. Wood & Co., of Arlington, Massachusetts, where the manufacture of ice-tools was established in 1834. "The plough was first made with wooden beams and with iron teeth, steeled and widened or upset at the point only. Next, iron beams of equal width were substituted for the wooden ones. Then followed various alterations, such as flanging the teeth the entire face so as to carry out the chips; making one beam wider than the other, to give room for the chips on one side; cutting out chip-spaces in the narrow beam, thus allowing the chips to shoot out freely from between its teeth and permitting the plough to run to its *full depth;* cutting out the bottom of the teeth, leaving only the heel and point to be fitted; making the best ploughs of *steel* teeth instead of iron and steel; improving the curve of the teeth; increasing the degree of finish, etc., etc." "Amongst some of the further experiments referred to may be mentioned, double-markers, combination plane and marker, teeth shaped like a lumber-marker, slanted back so as to *draw* through the ice, plows with sixteen teeth, gouge-pointed teeth, teeth with grooved spaces, called the lateral-cut, and many others."

A well-equipped ice company is provided with a full set of plows made to cut to different depths, so that one size may be used to follow another. There should be one 6-inch nine-toothed plow, one 8-inch, eight-toothed, one 10-inch and one 12-inch plow, and all of them used simultaneously, each following the other in the order of the depth of tooth. Each plow cuts about two inches at a run, and by having a full set and using them in sequence as described, a field of ice can be grooved much faster than where one plough has to do all the work.

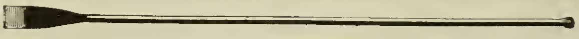
CUTTING A CHANNEL.

While the ploughing is in progress, or before, a channel is cut through the ice between the cutting ground and the incline or elevator, by which the blocks of ice are raised and delivered to the ice-houses. This channel is cut by plows which are allowed to cut nearly through the ice. The grooves so made are followed by saws, which complete the separation. A narrow strip of ice is thus cut free from the surrounding surface, and is then pressed down and under the main ice sheet, and a wider strip can then be cut loose and sunk, or harvested if suitable.

The channel being opened, and the elevators in readiness, the next operation is to detach large floes of the grooved ice and float them towards the elevator. This is accomplished by first sawing in the grooves across the ends of the block or "float" desired. Such a float, if there is sufficient space, may be 100 feet or more in length, large enough to sustain the weight of several men. It is common to cut them seven or eight cakes (of 44 inches square) wide, and ten or twelve cakes long. The sawing is done at right angles with the open water-space into which the floes are to be forced; there is thus but one long side to be detached, and this is split off the main body by "breaking-bars," broad wedge-shaped chisels. It is sufficient for workmen to follow along one of the grooves and to plunge this broad wedge into it at intervals with considerable force; a crack is thus started and can be followed up and extended the full length of the floe. When the separation is complete, the mass slowly floats away into the open space, and is directed through it to the channel by the workmen with long ice-hooks, or by lines extending to the firm ice around the open space.

Breaking-bar.

The floe is then to be divided up into long strips, by means of fork-bars; three men striking together in the same seam at intervals until the strips are detached. These may be one or two cakes wide, according to the elevator, either single or double. These long strips are then floated into a narrow channel leading up to the foot of the elevator, and as they pass along, one or two men stationed at the side of the canal on a plank platform, separate the cakes by striking lightly in the transverse grooves with a "canal-chisel," a tool six feet long, with a hollow handle to secure lightness.



Canal-chisel.

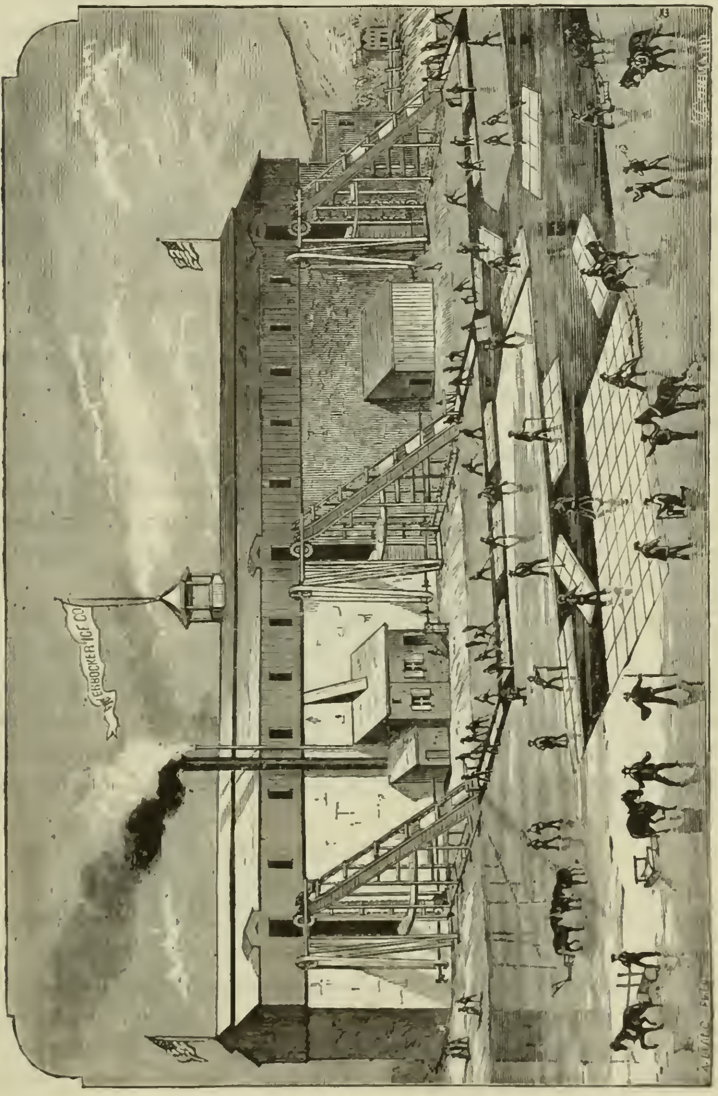
The whole of this series of operations, together with the arrangement of the elevators and ice-houses, are well shown by the wood-cut for which I am indebted to the courtesy of the Knickerbocker Ice Company of Philadelphia.

ELEVATION OF THE ICE.

The ice is lifted from the water by steam-power high enough to be distributed on ways, by sliding, into any part of the ice-house. The apparatus generally used is an endless-chain working on an inclined plane, the lower end of which dips below the surface of the water. The chain is double, consisting of two single chains side by side and about five feet apart, for 44-inch cakes, with wooden cross-bars connecting the chains at intervals of 6 feet. Large, open, rectangular spaces or links are thus formed large enough to admit a cake of ice between the bars, which extend across between the two strings of the chain.

The ice-cakes, as they are separated from the long strips in the channel, are pushed forward to the foot of the inclined plane over which this chain is moving, and being caught by the cross bars are carried along up the incline, each link or space on the chain taking one cake and depositing it at the first opening made in the floor of the incline, the cakes dropping through upon the platform of a second incline or guide-way with a gentle descent in the opposite direction, leading into the building. A series of such platforms and guideways is requisite. They are built one above another, about six feet apart, until the upper one will deliver the ice to the highest point, or layer, to be filled in the building. The lowest comes first into use, and the others in succession, as the building fills up with ice. Usually four runs are sufficient. When there are several ice-houses placed side by side, the guide-ways or runs are made to pass the doors of all the houses, and the ice can be turned at pleasure into any of the houses.

The construction of an overshot inclined plane elevator and endless chain is shown on the accompanying cut, showing also the driving pulley and gearing. It is arranged with a stairway alongside the chain for the convenience of the workmen. Six platform-runs are shown, the lowest one only being prolonged to the ice-house.



Ice-cutting scene, with the endless chain in operation.

The elevator-chain is moved by steam power. The speed varies at different places and under different conditions. The highest rate of movement brought to my knowledge was obtained on one chain (with five-feet spaces for 44-inch cakes and the cross-bars six feet apart) where 50 blocks were raised to the minute, each block being 44 inches square and 15 inches thick and weighing fully 1,000 pounds each. This lifting was thus at the rate of 25 tons a minute or 1,500 tons per hour.

To receive and stow away such an enormous supply, it is necessary to have at least twelve doors or houses to deliver into. Two men are stationed at each door, and as the cakes of ice sliding down the guide-way pass the door-way, the men select the cake due their door and pull it in by means of ice-hooks upon a branch guide-way or run leading into the building. When once landed upon the floor of ice already laid down in the house, the men stationed there receive the blocks and slide them into their proper places, side by side and tier after tier. To facilitate storage in large houses, movable slides and switches are used to guide the cakes of ice to different parts of the building, thus saving time and labor.

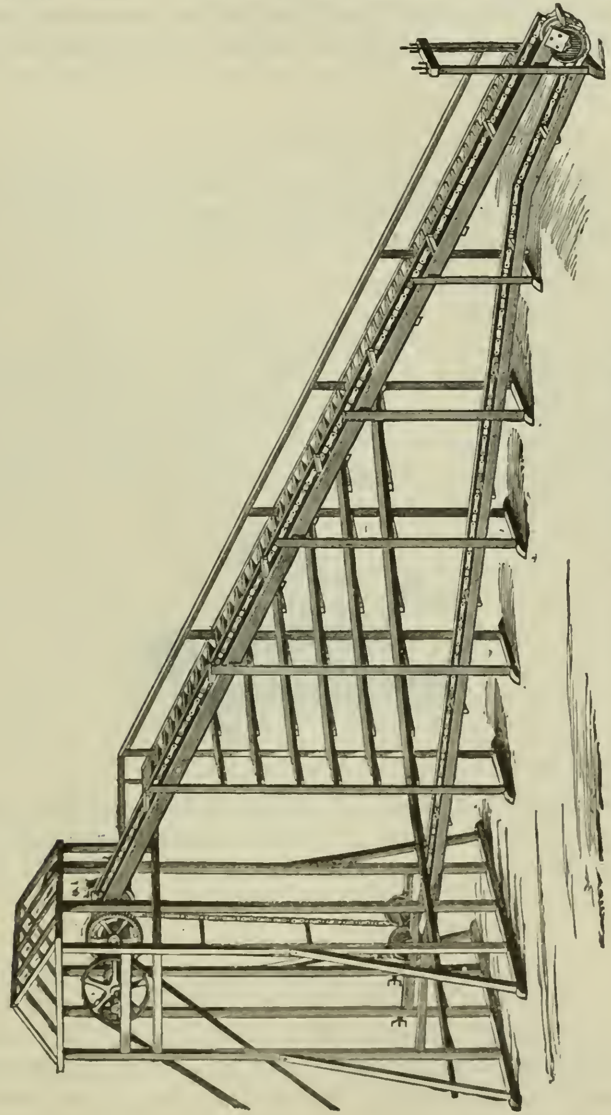
Another form of apparatus for lifting the ice has been invented, and is recommended by the Knickerbocker Ice Company of Philadelphia. It consists of a revolving vertical spiral platform, a screw elevator, which takes up cakes of ice from the water and delivers them at any required height to the runs leading into the ice-house.

The grade of ice-runs is an important matter. If too steep the ice will move with great velocity, and be more or less broken up; if too slight, there will be a loss of time and labor. With ice ten inches thick and upwards, the grade may be $\frac{5}{8}$ of an inch to the foot, and if less than ten inches thick, the grade may be $\frac{3}{4}$ of an inch to the foot. In warm weather the ice does not run as freely as when it is cold, and the ice is dry.

ICE-HOUSES AND STORING.

The most improved ice-houses are now built 100 or 150 feet long and 40 feet wide. This width is found in practice to be the most convenient, so much so that even if a large house is built under one roof, it is divided up inside into apartments from 36 to 40 feet wide, for when the ice slides down the centre-line of the house on the run, it is conveniently near either side, so that on reaching the end of the run (made in ten-foot sections) it is easily directed or "shunted" to the place it is needed to fill.

In storing, the cakes are placed so as to leave a 3-inch space all around them to prevent undue wasting when they are broken out in the summer season for delivery. It therefore becomes necessary to break joints every few tiers as they are laid up, by lapping the cakes over in such a way that the joints are covered. In Maine it has been

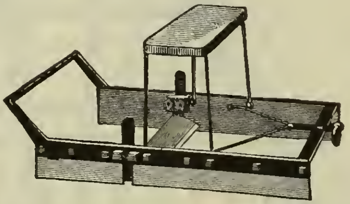


Overshot inclined-plane elevator and endless chain.

the custom to cut the cakes of ice 44 x 22, thus giving a rectangular block, with which it is easy to break joints in packing. It is now, however, becoming common on the Kennebec to cut the blocks 22 x 32, known as the "New York size;" 22 x 22 is rather too small, and 22 x 44 is too large. Some cut the blocks 22 x 30 and also 22 x 28, but all for shipping.

PLANING.

The ice-field when covered with porous snow-ice to any great depth, must be *planed* off, the snow-ice being too hard to yield to the scrapers. The operation is performed in the following manner: After the marker-grooves have been made and at a distance not exceeding 22 inches, a machine called the snow-ice plane, constructed as shown in the figure, is used. The sides of this plane are 22 inches apart and are fitted to run in the grooves made by the marker. If drawn by two horses as much as three inches can be taken off at once. If more snow-ice than this must be removed the plane must be run over the surface a second time. The shavings or chips from the first planing must be removed by scrapers. This is often a disagreeable operation, as the chips are flat and sharp and often cut the horses' legs and are difficult to pile up, especially when the weather is cold. The operation of planing is always avoided if possible.



Snow-ice plane.

COST OF CUTTING AND STORING ICE.

The cost of cutting ice and packing it away in the ice-house varies greatly, according to the varying conditions and the perfection of the arrangements and the skillful use of all the appliances. With an unlimited supply of good ice, say 10 to 12 inches thick, the cost may be as low as 12 cents per ton. At an ice-house where some 10,000 tons were harvested during the past winter the cost was estimated at 15 cents per ton. The average cost is nearer 25 cents.

When the crop is abundant it is not unusual for the owners of the plant for filling large ice-houses after the houses are filled, to continue cutting for the benefit of persons who wish to fill private ice-houses. This is practiced near some of the populous cities and villages within carting distance from the lake or river. Ice, the past winter, was sold in this manner at Lake Whitney, two miles from New Haven, at 40 cents per ton on the platform by the roadside ready to load into wagons. The cost of carting to the city was from 50 cents to 60 cents per ton, being more than the cutting and raising the ice to the platform.

WASTAGE AND LOSS.

But the first cost of the ice, as stored away in the ice-houses, is not a just basis of an estimate of its final cost to the ice-dealer when it leaves his hands and passes into those of the consumer.

The loss in weight of ice by melting, evaporation, and breakage is very great, and is an important item in the business, for although ice may be gathered and housed at an apparent trifling cost, only a fractional part of the quantity harvested is utilized. One dealer, who puts up some 10,000 tons yearly, estimates the wastage at 25 per cent. by melting in the houses during the season, 25 per cent. in taking out and carting, and of the remaining one-half there is often a loss of 33 per cent. in retail vending, or a total wastage of four-sixths of the entire amount stored. This is probably a large estimate. Others place the loss by melting from the close of winter to the end of the season at 25 per cent., and an additional loss of 25 per cent. to 30 per cent. in carting and delivering to consumers.

CHIEF CENTRE OF ICE INDUSTRY.

It is estimated that the consumption of ice in the city of New York is upwards of 700,000 tons annually, with an annual increase of 15 per cent. There are fifteen or more ice companies, besides small dealers who buy of the large companies. The manufacture of artificial ice does not appear to affect the demand for the naturally-formed article.

The Upper Hudson is a great source of ice for the New York market. Those who travel between New York and Albany, either by boat or by rail, cannot fail to notice the many large ice-houses which crowd the banks in some places from Troy and Albany as far down as Rhinebeck, Rondout, and Kingston. The river not only yields the product, but in summer gives it cheap transportation.

The conditions for the ice industry are thus exceptionably favorable. Full statistics for the present year* show that there are nearly two hundred ice-houses along the river, with a storage capacity of from 500 tons to 60,000 tons each. The total amount harvested this year is not less than 3,000,000 tons,—one of the largest harvests of ice ever gathered along the river. The ice-crop for the past six winters has been as follows:

Year.	Harvested Tons.
1878	2,408,500
1879	2,061,500
1880	150,000
1881	2,500,000
1882	2,000,000
1883	3,000,000

A considerable part of this ice was from eight to ten inches thick, and some of it was fourteen inches thick. The harvest commenced as early as December 8th, but a thaw interrupted the work, and it was not actively resumed until January 8th, 1883, and the principal houses were filled within the next thirty days.

A favorable winter for ice on the Hudson and an abundant harvest, makes it less desirable to lay in a heavy store at the ice-houses in Maine. On the other hand, an unfavorable season in New York is advantageous to the more northern dealers.

The Kennebec River in Maine is also a favorite region for harvesting ice. It has the advantage of rigorous winters and the crops rarely fail. The deep inlets and ponds give easy access to vessels and cheap transportation to domestic and foreign markets. Several of the principal ice companies of New York, Philadelphia, Baltimore, and Washington have large ice-houses along the stream and secure a supply there when the winter fails to give the required crop nearer to their consumers The greater part of the Kennebec, from Bath and Woolwich up to the dam at Augusta, is marked off to different ice dealers and is dotted with ice-houses. A map of this region, with a full list of the companies and firms engaged in the ice business, and statistics of the production of ice in Maine, is published annually by Mr. A. G. Chase, of Gardiner, Maine. Considerable quantities of ice are gathered along the Penobscot, the Cathance River, and along the coast, as will be seen by the annexed summary for the years 1882 and 1883.*

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* Published by the Albany *Evening Journal*, January, 1883.

Locality.	Year 1882.	Year 1883.
Kennebec	1,029,200	931,900
Penobscot	146,000	112,000
Cathance	39,000	22,700
Coast	349,000	297,900
Total, tons	1,563,200	1,364,500

The falling off is attributable to the abundant harvest on the Hudson and at other points.

Besides these main centres of the ice industry, ice-houses are scattered over the interior of the New England and Northern States, and full statistics of the annual ice production are not readily attainable. At New Haven, Conn., for example, the main supply is from Whitney Lake, where 10,500 tons were harvested this winter, and from Lake Saltonstall.

Upon the Pacific Coast ice for the San Francisco market is harvested in Alaska, partly at Sitka and partly at Kodiak, the winter at Sitka often not being sufficiently severe to make thick ice.

The ice interest of the country is sufficient to sustain a monthly paper devoted to the ice trade.† It is published by the Knickerbocker Ice Company of Philadelphia. This company is organized on a basis of $1,500,000 capital. It has 250 delivery wagons and employs 800 persons. The total annual ice-crop of the United States is estimated at 20,000,000 tons, and the consumption 12,000,000 tons, the difference being waste.

Phases of Electric Vibrations.—A. Oberbeck publishes investigations which lead to the following law: If electric waves, which are synchronous, but have different phases, flow through the fixed and the movable roll of an electro-dynamometer, the deviation of the movable roll is proportional to the product of the maximum intensity and the cosine of the difference of phase.—*Ann. der Phys. u. Chem.*, Nov., 1882.

C.

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* Figures for 1882 from Chase's map, and for 1883 from the *Ice Trade Journal.*

† *Ice Trade Journal*, Philadelphia.

APPARATUS FOR ESTIMATING CARBON IN STEELS.

By Addison B. Clemence, Worcester, Mass.

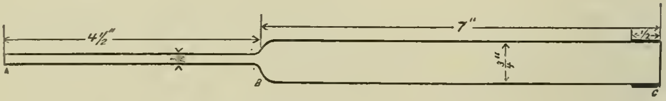
A description of the apparatus in use at the works of the Washburn & Moen Manufacturing Company, of this city, will, I think, be of interest to those who desire an accurate method for the estimation of carbon in steels. The apparatus has been in use in the works for the past three months, and has given entire satisfaction.

The method of filtering carbon on to asbestos in a glass funnel, drying, transferring to a porcelain tube, and burning in a stream of oxygen gas, is accurate if all the carbon can be separated from the sides of the funnel, which in some cases is almost impossible.

Again, the method of filtering on to asbestos in a platinum tube or boat-shaped apparatus, and putting all in a porcelain tube and burning as before, has also been used, and of course is less liable to error.

My aim has been to do away entirely with the porcelain tube and combustion furnace, and to filter and burn in the same tube.

The sketch shows the form of apparatus I have adopted, being made of platinum.



The following is the process I use: Dissolve from 3 to 5 grams steel borings in double chloride copper and ammonium, using 36 grams of the salt to 120 cc. water for 3 grams of steel.

After the separated copper has completely dissolved, filter on to a plug of ignited asbestos placed at (*b*), and wash thoroughly with hot water. Any carbon that adheres to the sides of the tube may be swept down with moistened asbestos.

The tube is then placed in an air-bath and dried at a temperature of 150° to 175°C. for about one hour. A hard rubber cork, through which is a glass tube, is inserted at (*c*), the oxygen gas passing from (*c*) to (*a*). Around the tube at (*c*) is a single thickness of filter paper, about two inches wide, kept wet by a stream of water supplied from a reservoir on a shelf above.

Heat is applied at (*b*) for one-half hour, at the end of which time the potash bulb is ready for the balance. One Bunsen burner is sufficient for the combustion.

The same precautions are taken to dry the gas before entering the platinum tube, as well as before entering the potash bulb, as in the case in the porcelain tube method.

Six burners of a combustion furnace will consume 14 feet gas in one-half hour, while one Bunsen burner will consume 2 feet in the same time.

The following table shows some results obtained by the "platinum tube" process:

A is a Swedish Bessemer, with ·10 per cent. of carbon;

B an American Bessemer, with ·18 per cent., and

C an American Bessemer, with ·50 per cent., all obtained by the "porcelain tube" process.

	A.	B.	C.
1.....	·09	·18	·49
2.....	·10	·18	·51
3.....	·10	·16	·49
4.....	·10	·17	·44

NOTE.—If pure, closely-woven asbestos cloth can be obtained, I see no reason why with two potash bulbs, twelve combustions may not be made in one day, for each filter with its contents may, when dried, be put in the platinum tube and burned.

Worcester, September, 1883.

Incombustible Paper.—G. Meyer has submitted to the Société d'Encouragement specimens of incombustible paper and card board. The base of the paper is amianthus; but it was necessary also to invent inks which should be both indelible and incombustible and which could be employed in writing, printing, lithographing, etc. One of his lithographs when placed between two layers of melted glass resisted the action of heat. It remained uninjured and the engraving preserved all its sharpness.—*Chron. Industr.*, March 25, 1883. C.

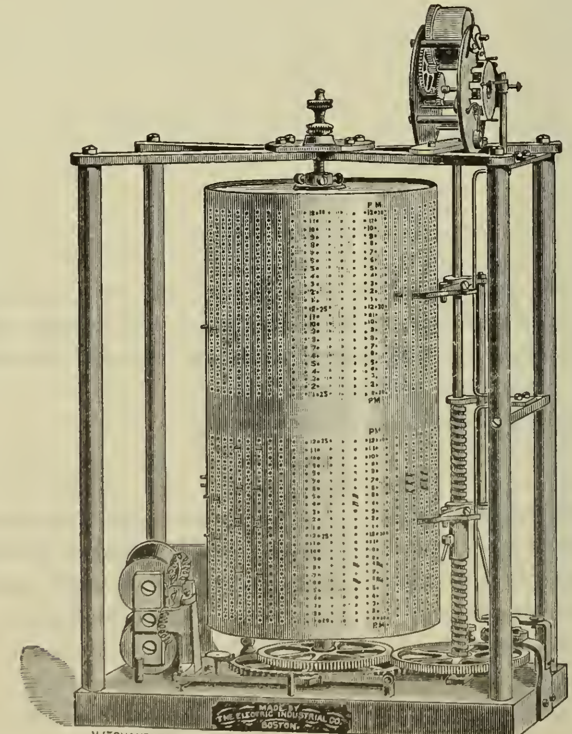
AN ELECTRIC SIGNAL CLOCK.

[Report of the Committee on Science and the Arts.]

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, September 5, 1883.

The Committee of the Electrical Section of the Franklin Institute of the State of Pennsylvania, to which was referred for examination Blodgett Bros., of Boston, Electric Signal Clock, report that they have examined the invention, and find its purpose and construction substantially to be as follows:

The instrument is designed—1st. To give any kind of fixed signals at any regular or irregular intervals, and especially, 2d. To cause the striking of warning and departure signals for railway trains or street cars, according to the time table in use. In general, it is intended for all purposes where any sort of time signals is required.



V.L.CHANDLER SC.

In the following, we give the peculiar features and manner of operation of the instrument.

An electro-magnet is connected by wires to a standard clock, which closes an electric circuit once every minute. This magnet, by means of a lever and a pawl, rotates a ratchet-wheel of sixty teeth one step each minute. The wheel is rigidly attached to the axis of a vertical cylinder fourteen inches high, and six inches in diameter, which revolves with it, and therefore makes a complete revolution once in an hour. The cylinder has two divisions, each of which is provided with a hole for every minute of twenty-four hours, or 1,440 holes in all, arranged in a single spiral.

A toothed wheel on the axis of this cylinder, gearing into another of equal size, imparts its motion to a coarse-threaded screw, which raises, at a rate uniform with the movement of the cylinder, a small sleeve or follower, consisting of a short lever with two arms, the forward end of which passes very near to the surface of the cylinder. The rear end of this lever is forked, and gives a lateral movement to an elongated crank, and also, by means presently to be described, to a vertical rocking shaft, bearing at its upper end a horizontal bar, adapted alternately to engage with and release stop pins of a circuit wheel.

Whenever the vertical shaft is slightly rotated, the circuit wheel (which is driven by a spring clock movement) is released, and moves on a short distance.

For railroad purposes, two signals are usually required for every train; a warning or preliminary signal, which precedes the other by an interval of from two to five minutes, and a final or departure signal, sounded at the exact moment when the train should start. To effect this operation, short pins are inserted into the holes of the cylinder, which correspond in location to the times of all the warning and departure signals. The lower division is arranged according to the week-day time-table, and the upper one according to the Sunday time-table. The follower passes over every hole in the cylinder once in twenty-four hours. When, in the course of its traverse, it comes in contact with the first of the two pins for any train, the end is moved away from the cylinder a short distance, and by a small rotation of the vertical shaft, deflects the horizontal bar far enough to allow a pin to pass, and thereby set the circuit wheel of the clockwork in motion. This wheel has upon its circumference a series of projections or pins, which, when the wheel revolves, come in contact with a fixed spring. The projections and spring close an electric circuit through the signal bells a certain number of times, depending on the signal to be given. When the follower comes in contact with the pin denoting the time of the second or departure signal, the operation is repeated, except that there are a different number of projections on the circuit wheel, and so a different number of strokes upon the bells, corresponding to the distinctive character of the final signal. When the time of the next train approaches, the same movements are repeated, and so on through the entire day. At midnight the follower has completed its traverse of all the holes in the cylinder, and it is then automatically detached from the screw by a cam, and falls freely to its position opposite the first hole in the series, where it becomes again attached to the screw, and begins a new day.

A second follower, also connected with the elongated crank, moves in like manner over the upper part of the cylinder; but it cannot put in motion the striking mechanism during a week-day. On Sunday, however, it is rendered operative, and the lower one inoperative, in the following manner: Each of the elongated cranks, before described, is attached to a sleeve, fitting loosely on the rod, carrying the horizontal detent bar. It communicates its motion to this rod by means of a slot in the sleeve, engaging with a pin, running transversely through the middle of the rod, in such a manner that a slight movement downward of both sleeves, will disengage the lower one from the rod, and the pin will engage with a slot in the upper sleeve, which can then rotate the rod and detent bar, against which the stop-pins rest; while now the lower one turns freely about the rod, without affecting the mechanism in any way.

The weight of the sleeves is carried by a cam attached to a ratchet wheel of seven teeth, which revolves around the vertical rod. In the descent of the follower at midnight of each day, it moves this seven-toothed ratchet wheel and cam forward one space.

One-seventh of the circumference of the cam is depressed considerably below the level of the remainder, which is horizontal. The sleeves are supported by a pin, which during six days of the week rides upon the horizontal surface of the cam; but at midnight, Saturday, it falls into the depression, lowering the sleeves, and thereby disconnects the lower one from the vertical rod and bar, which control the striking mechanism, and engages the upper one. For this day, then, the pins in the upper division, corresponding to the Sunday time-table, operate the signal bells, and those for the week-days have no effect. With the next transfer of the follower at midnight, Sunday, the pin is lifted out of the depression of the cam, and the week-day time-table is resumed.

These operations are repeated week after week, requiring no other attention than the winding of the spring of the clock movement which drives the circuit wheel, once a week, or at longer intervals, according to the number of trains.

There are some peculiar features to be noticed about this machine. Instead of the usual arrangement of a stationary magnet and a movable armature, the magnet which rotates the cylinder is pivoted on a vertical axis near the base of the coils of the magnet (which are in a vertical plane), and the armature is stationary. Both have curved surfaces, which are arranged eccentrically to each other, in such a manner that the movement of the magnet, when the current passes, brings it constantly nearer to, but never in contact with the armature. Its path is limited by a stop. When the electric circuit through the coils of the magnet is broken, a repelling spring returns it to its first position. The cylinder is prevented from moving backward by a fixed pawl engaging with the teeth of the ratchet wheel; and from going more than one space at a time, by a wedge-shaped projection on the pawl which rotates the cylinder, coming in contact with a stop at each movement, and preventing further motion of the wheel.

The operation of changing the time-table for a new schedule, consists simply in removing the pins, which are screwed into the cylinder, and placing them in new holes. The holes are numbered for every five minutes, to facilitate this operation. The number of signal strokes may also be easily changed for a different number of blows in the series, by simply substituting for the circuit wheel another with a different number of projections. Three or more blows may be given for each train instead of two, by proper arrangement of the projections on the circuit wheel, and corresponding limits of motion by the stop pins.

The instrument has no parts that are easily deranged, nor are its adjustments difficult to be made.

The wear is very slight, and the parts are all accessible for repairs, should any such be necessary.

Believing that Blodgett's Electric Signal Clock is not only an invention that will answer the purpose it is designed for, accurately and effectively, but that it also solves some complex mechanical problems simply and ingeniously, we recommend that Blodgett Bros. receive the award of the Scott Legacy Medal and Premium.

Approved, September 5, 1883.

H. R. HEYL,
Chairman Committee Science and the Arts.

Attest: WILLIAM H. WAHL,
Secretary.

Book Notices.

THE WATCHMAKERS' HANDBOOK. By Claudius Saunier. Intended as a Workshop Companion for those who are engaged in Watchmaking and the Allied Mechanical Arts. English edition. Translated, revised and considerably augmented by Julien Tripplin and Edward Rigg, M.A. Illustrated by numerous wood blocks and copper plates. London: J. Tripplin, 5 Bartlett's buildings; and at the office of "The Watchmaker, Jeweller and Silversmith," 11 Saint Bride street. 1882.

In the Preface of this book the author makes the following assertion, which is strictly correct: "In recent years the work of ordinary watch-jobbers and repairers has undergone considerable change. The apprenticeship he serves, if indeed it can be called a real apprenticeship, is shorter than formerly. The immense number of badly constructed watches he is called upon to put in going order for a trifling remuneration compels him to replace the older methods of procedure by others whenever by so doing time can be saved." And we agree with him when he further says "that from this point of view the value of the present Handbook can hardly be over-estimated, since it contains, in readily accessible form, many details as to the working of metals and descriptions of various practical operations, new and improved forms of tools," etc.

The purpose of the book could not well be better defined than in the above-quoted words of the author. To all who lack the experience of a thorough apprenticeship in watchmaking this book will be a source of information well worth their attention. The contents embraces such information only as the jobber and repairer is especially in need of, and on matters belonging to horology as a science he frequently refers to his "Treatise on Modern Horology," to which he considers the work before us a "companion."

The book is divided into six parts.

Part One, devoted to Arithmetic, Geometry and Measurement, giving short but very comprehensive instructions on these subjects.

Part Two, to the Materials used in Horology, how to prepare and treat them, what purposes they have to serve and where they are applied. The metals, the chemicals, the minerals and other natural products are sufficiently considered to serve the object of the book.

Part Three has "Health and Manipulation" for its subject, and gives brief advice and instruction on the different subjects which are well worth observing.

Part Four speaks of the outfit of the workshop in general, and is very important. It describes all necessary tools and appliances, and the manner in which they are used, minutely and well.

The subject of *Part Five* is the "Repairing and Examining of Watches."

The "Practical Receipts" of *Part Six* are a supplementary addition to the book, describing many practical ways of doing work not mentioned in the other chapters.

The book is a mine of useful information. Its illustrations are well executed and numerous, and the index enables one to find references readily. L. H. S.

THE NATURE OF HEAT AND GRAVITY. By William Coutie: Troy, N. Y.: H. Stowell, printer, 1883.

The writer of this pamphlet speaks of himself as "one who, in one point at least, was the first of all living men in the most difficult subject that has engaged the attention of this generation" (p. 18.) In this belief he is mistaken, for there are many men living who have entertained similar views, and his hypothesis, that light, heat, and gravity are "only different manifestations of the self-same thing," is at least as old as the days of Lucretius. It was virtually adopted by Newton, in his study of the laws of gravitation, and more fully and definitely expanded by Le Sage.

So far, however, as the hypothesis has been independently thought out, it has a special interest, as giving additional evidence of a natural, instinctive belief, which furnishes grounds for further investigation;

and so far as an attempt has been made at numerical confirmation of that belief, there has been a working in the right direction. For example, on page 10, the fourth postulate is as follows:

"The planets, in moving around the sun, have their motions reversed from direct right lines twice in every revolution, and by (3) the force required to do this is equal to four times the force required to impart to them their present energies."

The table of planetary data and of hypothetical resultant "reversing force," which accompanies and illustrates the postulate, however fanciful it may seem at first glance, may, perhaps, find some justification in the hypotheses of Siemens, in regard to the conservation of solar energy, and of Eddy, in regard to the questionableness of the second law of thermodynamics. Chase's application of the principle of "the dynamic head" to an explanation of the dependence of all the motions in the solar system on the wave velocity of light (*Proc. A. P. S.*, vols. ix–xxi), de Senlis's comparison of the sun to an incandescent electric lamp working in an absolute vacuum (*Les Mondes*, Jan. 6, 1883), and Duponchel's attempts to show how the heat which is emitted can return by a closed circuit to the focus of departure (*Revue Scientifique*, Jan. 27, 1883) may also be consulted in the same connection. C.

PAINTING AND PAINTERS' MATERIALS; a book of facts for painters and those who use and deal in paint materials. By Charles L. Condit, under the supervision of Jacob Scheller, master painter. Published by The Railroad Gazette, New York, 1883, pp. 461.

This is a very thorough treatise on an important, and by no means hackneyed subject—the treating of oils, etc., in relation to paints, varnishes, and colors; also directions as to decoration of interiors and exteriors, the erection and management of paint shops, the painting of railroad cars, carriages, etc. There are chapters on the manufacture of white and red lead, and their effects upon iron and wood, also a chapter on putty and brushes, and one on the much neglected subject of the effects of paint upon the health of the workmen. The testing of materials and the drying qualities of oils, turpentine and benzine, together with the proper mode of mixing colors to obtain certain shades, are subjects treated in a most lucid manner; and the more technical points of the chemical relations of pigments are explained in a way, showing that the authors are thoroughly acquainted with their subjects. There is an appendix with much valuable information, lists of works for reference, etc., and the volume has a number of handsome illustrations. This treatise must be valuable to any one engaged in painting and decoration, also to a large class of color men, druggists and others, whose business has near relation to this specialty. The volume is literally packed with information, conveyed with a clearness and conciseness which waste not the time of the reader. N.

A PRACTICAL TREATISE ON LIGHTNING PROTECTION; giving complete and explicit Instructions for the Protection of Buildings, and explaining the Defects of Lightning Conductors now Erected. By Henry W. Spang. With illustrations. New and revised edition. New York: D. Van Nostrand, 1883. 8vo, pp. 63.

The present treatise presents in condensed form the general considerations respecting the proper measures to be taken to protect buildings against injury or destruction by lightning which appeared in his earlier treatise on the subject, published in 1877, and which was noticed in the JOURNAL at the time of its appearance. (*Vide* vol. civ, p. 79).

The general views advanced by the author in the present work, are substantially the same as those advanced in his previous work, while the feature of advocating his own particular system and the wholesale condemnation of others is even more pronounced.

It is fortunate for Mr. Spang that his system is in all respects a good one, for this fact serves as a mantle to cover a number of violations of the proprieties in his criticisms of others.

Aside from this fault we may cordially commend the present volume as conveying sound and safe views on the subject it treats of.

Briefly stated, Mr. Spang's system consists in providing an ample number of metallic conductors upon the building to be protected (*i. e.*, an air-terminal conductor upon each of the corners, to protect every portion), connecting these "metallically" with each other, and with a perforated pipe not less than ten feet long, and two inches internal diameter, leading into the earth. This earth connection, which is the distinguishing feature of Mr. Spang's plan of protecting buildings, should be so situated that the waste water from a hydrant or pump, and the roof, "will readily enter it through its top opening, and, passing through its lower and side openings, cause a suitable area of earth around and beneath it to become and remain moist . . . and thereby effect an easy electrical path between the lower end of the pipe and the subterranean water-bed."

The plan is undoubtedly an excellent one, and in accord with the best practice known to electricians, namely, to employ metallic conductors of ample dimensions upon the building, and to connect these in as perfect a manner as possible with the earth, by carrying their lower terminals down to permanent moisture, or connecting them suitably to a large body of metal.

Mr. Spang, in the course of his work, very plainly exposes certain prevalent errors in connection with the subject of erecting lightning rods, of which it will suffice to mention the inutility of points upon rods, and the folly of insulating the rod from the building. He advocates the connection of the metallic roofs, gutters, leaders, with the ground system, and the employment of gas, water and other inside pipes, as additional protectors, by suitably connecting them with the air-terminals of the rods.

There can be no question that Mr. Spang's plan of protecting buildings, when properly applied, is one of the best that can be devised, in the present state of our knowledge. W.

PRACTICAL CARPENTRY; being a Guide to the Correct Working and Laying Out of all kinds of Carpenters' and Joiners' Work, etc.; to which is prefixed a thorough Treatise on "Carpenters' Geometry." By Fred. T. Hodgson. New York: The Industrial Publication Company, 1883. 12mo, pp. 144, 6 plates.

The title of this work expresses its scope and character very well. It is written by an author who has had some experience in the preparation of workshop manuals for workmen, and who has made a creditable reputation thereby.

The average carpenter, whose time is so fully occupied in the shop that he has little to spare for home study to acquaint himself with many geometrical principles that he nevertheless constantly feels the need of to assist him in laying out his work, and in getting at the readiest, most economical and advantageous methods of performing it, will find Mr. Hodgson's book a useful companion to occupy a corner in his shop or tool-chest, where it may be handy for consultation.

This is the purpose for which the author has prepared the work, as in his preface he desires it to be understood that it "is not intended to take the place of any of the larger and more exhaustive works, but is designed more particularly for use as a handbook by the workman who has not had time or opportunity to thoroughly commit to memory the principles it contains. . . . There are many whose limited means will not permit of their purchasing a great number of these books, . . . and it is for these men that this manual is prepared."

Briefly summarized, the book is a guide to the correct working and laying out of all kinds of carpenters' and joiners' work, with the aid of a series of illustrated problems, giving the solutions of a great variety of questions that arise in correctly laying out and executing the more troublesome operations that every carpenter is constantly meeting with in his trade. These embrace problems in hip-roofs, Gothic work, centering, splayed work, joints and jointing, hinging, dovetailing, mitering, timber splicing, hopper work, skylights, raking mouldings, circular work, etc., etc. The book contains also a number of useful tables for facilitating calculations, and, in addition to some 150 wood-cuts accompanying the problems, scattered through it with the text, it has six well-engraved plates showing various forms of joints and straps and hinges.

The rules and solutions given throughout the work appear, so far as we have been able to examine them, to be correct, and therefore reliable. Altogether it contains a large amount of useful information, conveyed in an intelligible manner, and it may be safely commended to workmen in carpentry as a serviceable reference book to have at hand. W.

Sand-sharpened Files.—The value of the sand-blast in sharpening files is not limited to the restoration of those that have been worn out, but it is equally evident in the first cutting. Experiments have been tried with bastard files which were finished by the sand blast upon one side, while the other side was simply cut in the ordinary manner; other files of the same size were also tried, which had been worn out and resharpened by the sand-blast. With these files three pieces of gun metal, of equal size and quality, were worked, by making fifty thrusts at a time upon each piece and continuing until one of the files became useless. A similar experiment was tried with cast iron, wrought iron, and steel, showing that the newly finished files were the first to give out and those which were finished with the sand-blast were the most durable of all.—*Dingler's Journal*, April 11, 1883. C.

The Du Puy Process in Spain.—In the year 1878, the proprietors of the *Gaceta Industrial* became satisfied that the Du Puy process, for the direct production of malleable iron from the ore, was a success; but not until the last patent was obtained were they satisfied that it had been brought to such perfection as to be susceptible of no further improvement except in minor details. The requirement of a wrought-iron canister added largely to the expense of manufacture under the first method; that necessity having been now removed, the ore and other ingredients are mixed in a mass with walls of small thickness, without any foreign envelope, and the reduction from the ore to the malleable ball requires only from two to three hours, in furnaces which are badly adapted to the process, and probably less than two hours in suitable furnaces. At first it was thought that a single furnace would not be able to produce more than four or five tons per day, but it is now found that they will yield ten tons or more with the same attendance when in regular operation. The whole process is so automatic that scarcely any supervision is required except in charging and removing the charge. It would be absurd to suppose that this interesting method is to be the only one, or even the prevailing one, in the iron industry; but it is certain that it will always occupy the first rank, and it will form a part of the operations in all large establishments, while it will be the exclusive one in small works. Large manufacturers will absolutely require it, since at the present time they have from 3,000 to 4,000 tons of waste cinder and other refuse, annually turned out from their puddling and heating furnaces and Bessemer converters, which could be made to yield, by the new process, from 40,000 to 50,000 pesetas ($8,000 to $10,000) per annum. In small fabrics the method should make its way exclusively and with certainty, because there is absolutely no way of producing small quantities of malleable iron or Martin-Siemens steel at less cost or with less capital. Moreover, the process may be employed in the production of malleable iron of the best quality, quite equal to that which is made from charcoal pigs, at a cost even less than coke iron. Du Puy's system, therefore, can be applied with visible advantage to all cases in which the Catalan or Tourangin methods are now used and to all cases in which, by utilizing the small and hitherto ruinous furnaces of olden time, the production may be triplicated. The only defect is, that the new process does not economize the ore quite so well as more expensive methods; but that is a slight consideration in Spain, where the works can be established at the very foot of the mines and where the value of the rich, pure, plentiful and cheap iron ores is only a subordinate consideration. The cost of the slight excess in ore is more than made up by the economy in fuel, the quality of product and the saving in investment. The system seems to be especially adapted to Spain, and the times are quite ripe for its introduction. Repeated trials have been made in Madrid, most of them with a greater or less degree of privacy, but some of them have been of an official character and attended by some of the best Spanish industrial and mining engineers. Señor Don Constantino Saez Montoya was commissioned by the Conservatorio de Artes y Oficios to test the working of the patent; Don Federico Bayo, Don Saturnino Otaegui, Don Luis Barra, Don José Alcover, Don Baldomero Santigos, and Don Juan Gomez Hemas were also in attendance, to represent various syndicates and manufacturers. The operations were conducted under the intelligent direction of Mr. Howard R. Justice, a Philadelphia engineer and son of the proprietor of the European patents. The Rubio ores of Bilbao were employed, assaying 50·29 per cent. From the first operation the proper mixture for reducing the iron was made without difficulty, so as to secure the two aims of commercial success and quick reduction. The charge was reduced in two hours and three-quarters, and was drawn from the furnace in balls as large as the doors would allow; the yield was a ton of hammered blooms for $2\frac{3}{8}$ tons of Rubio ore; at other times a ton of blooms was obtained from $2\frac{5}{16}$ tons of the same ore. It is customary to employ the best coal in such tests, but the operators purposely used Puertollano coal of an inferior quality, in order to demonstrate the double advantages of their method. The iron obtained was of a very satisfactory character, although it was wrought by a very unsuitable hammer. The witnesses of the operation were all of great industrial competency, capable of readily appreciating the fact that the work was performed under unfavorable conditions, and that it nevertheless yielded good results. The moulds were introduced into the furnace while still moist, and they were charged while the furnace was still cool, out of courtesy to the official engineer, in order to occupy as little of his time as possible. The furnace was of the worst type that could be employed for the purpose; direct-firing, with low doors, horizontal grate, very low open ash pit, and cold draught. A proper Du Puy furnace should be gas-heated, with large doors, closed ash pit, and forced draught at low pressure but high temperature. To obtain a good yield from ores in these unfavorable conditions is a much better evidence of success than to reach ideal results with the best means.—*La Gaceta Industrial,* June 25, 1883. C.

Astro-Photographic Studies.—Since 1874, C. V. Zenger has made photographs of the sun with an astro-photographic apparatus constructed by Browning. He operated with an ethereal solution of chlorophyl, from which he extracted a compound by treating it with sulphuric ether and dried peppermint. He thus obtained a deep green liquid, which could be reduced by the evaporation of the ether to a friable, black, and aromatic substance, which contains ethereal oil of mint. By benzine, pure alcohol, and paraffine, three coloring matters can be separated: green chlorophyl, indigo-blue cyanophyl, and reddish-yellow xanthophyl. Each of these substances has its special absorption-spectrum; when united they absorb nearly all parts of the solar spectrum. In this manner he succeeded in representing the solar corona and the chromosphere, sometimes with a reddish or yellowish color, when the sky was very clear and cloudless. He even obtained the representation of a solar halo, on the 10th of January, 1875, with all the colors visible to the naked eye; these colors remain still unchanged. He obtained a photograph of the solar spectrum, showing the lines from A to H, and even to J and M, when he used his quartz dispersion parallelopiped and quartz oculars or photographic lenses. On March 5th, 1875, he observed, during a heavy wind, some special phenomena to which he has given the name of zones of absorption. The sun's disc was surrounded by sharply defined elliptic zones, showing in the negative with snowy whiteness. Many of the photographs which were taken upon that day showed the phenomenon, which ceased only with the tempest. In repeating the experiment, he finds that these appearances are always manifested before and during heavy gusts; he has also found, during nine years of daily observation, that the phenomena are repeated regularly, at intervals of from ten to thirteen days, and that they indicate the approach of the storm from 12 to 24 hours, even before the barometer or the magnetic needle has shown any signs of disturbance. In examining observation which have been extended over long periods, covering 20 years at stations in Greenwich, Vienna, Prague, and Windsor in Australia, he finds cycles of from 12·7 to 13·1 days in storms and rainfalls. He also finds similar cycles in aurora borealis, solar photographs, American cyclones, Chinese typhoons, falls of bolides and meteorites, perihelia of comets, and earthquakes. In January, 1883, he communicated to the French Academy some of his results, comparing the dates of the most recent cometary perihelia, the durations of their sidereal revolutions and the duration of a solar half rotation, which led him to the equation

$$\frac{nt}{2} = T,$$

in which n is an integer, t the period of solar rotation, T the duration of the sidereal revolution of the comet or planet. He applies this equation to the eight primary planets and the asteroids Vesta, Juno, Ceres, and Camilla, showing that they all give values for t which have an extreme range of less than one per cent. He considers that the marvelous symmetry which is thus shown furnishes a striking example of the simplicity and perfect symmetry of the solar system, and that we can consider the same law of periodicity as governing the movements of planets, comets, meteoric displays, planetary atmospheres, aurora borealis, changes of electric and magnetic condition, and seismic movements. It therefore seems to him very probable that the sun acts as an enormous dynamo-electric machine connected with others, their mutual energy being manifested in determining all the movements in inter-planetary space and on the surface and in the interior of the planets themselves, and that their revolutions, like those of comets and meteorites, are only the movements resulting from the actions of the dynamic poles of this enormous source of energy.—*Comptes Rendus*, August 27, 1883.

[Zenger makes no attempt to explain his harmonies, but they may be simply accounted for on a principle which is given in Rankine's "Manual of Applied Mechanics," p. 576: "in a rotating vortex, the dynamic head, at any point, is the height due to the velocity, and the energy of any particle is one-half actual and one-half potential." Chase has applied this principle (*Proc. Amer. Phil. Soc,*, vols. ix–xxi) to an explanation of the dependence of all the motions in the solar system on the wave velocity of light. The hypotheses of Siemens and Duponchel, respecting the conservation of solar energy, may, perhaps, be more fully and satisfactorily elucidated by the same principle.] C.

Telluric Spectral Bands.—Admiral Mouchez has presented to the French Academy a note of M. Egoroff, upon the production of the fundamental telluric bands, A and B, of the solar spectrum, by an absorbing layer of oxygen. Angström observed the disappearance of the group *a* during heavy frosts, while *A* and *B* remained. We may, therefore, suppose that *A* and *B* are solar groups, or inter-planetary groups, or telluric groups which are due to other atmospheric elements than the vapor of water. The successive experiments made at the Paris Observatory, upon the successive absorption of atmospheric layers of different thicknesses, between the limits of 10,000 metres and 80 metres, have shown that *A* and *B* are telluric groups, and that *A* is the more fundamental of the two. Direct observations upon the absorption spectra of carbonic acid, ammonia, and ozone, taken in layers which correspond to atmospheric layers of more than 100 kilometres in thickness, have shown that those gases have nothing to do with the groups in question. Egoroff placed in the physical laboratory of St. Petersburg a tube, 20 metres long and 50 millimetres in diameter, in which the air or its constituent gases could be subjected to a pressure of 15 atmospheres. A Drummond light was concentrated, after passing through the tube, upon the slit of a large Merz spectroscope, by means of an achromatic lens having the same focal distance as the collimator. Air compressed with five atmospheres gives *A* plainly visible; under a pressure of eight atmospheres it becomes deeper, broader, and more distinctly marked. On adding oxygen to the air in the tube and maintaining the pressure of the mixture at seven atmospheres, *A* becomes very distinct, under the form of a double group, of which the more refrangible portion is darker than the other. Each group appears to be composed of a multitude of fine lines. Oxygen pure and dry shows *A* under the pressure of a single atmosphere. With a pressure of three atmospheres, it becomes plainly double. At a pressure of six atmospheres, it is largely developed and the group *B* is added. At eight atmospheres, the two groups are strengthened and enlarged. They are, therefore, due to the oxygen of the air. Hydrogen, under a pressure of three atmospheres, shows no trace of line or band in the visible portion of the spectrum. The same thing is true of ordinary illuminating gas, and of air saturated with benzine, which controverts the opinion of M. Abney that the groups are attributable to absorption by hydrocarbons in inter-planetary space.—*Comptes Rendus*, Aug. 27, 1883. C.

Dwarfs and Giants.—M. Delbeuf, in a late address to the Royal Academy of Belgium, skillfully attacks some of the common notions in regard to the relative degrees of force which are exerted by different forms of animal life. We are astonished when we first hear that a flea can jump 200 times his own length. Our admiration is changed into stupefaction when a simple calculation shows that if nature had endowed the horse with a like power, but increased in proportion to its weight, it would be able, at a single bound, to leap over the Rocky Mountains. If man had a velocity proportioned to that of certain insects, he would traverse more than ten leagues in a minute, which is 60 times the speed of an express train. The Amazon ants, in starting on a warlike expedition, travel about two and a half yards per minute. The celebrated heroines of antiquity who gave their name to these turbulent insects, would have traveled on foot eight leagues per hour, if their speed was proportioned to their size. We ought, however, to compare the forces which move given masses, and to consider the relative weights or volumes. Under this view, the warlike inhabitants of the banks of the Thermodon should have traveled 150,000 miles per hour. That is enough to frighten the boldest imagination. And yet who will deny the truth of the observations, the accuracy of the measurements, and the justice of the reasoning. In all such comparisons there is a scientific delusion which may be easily dissipated. The proper subject of consideration is the work necessary to raise a certain weight. The work increases in joint proportionality to the weight and height. When two animals, of different masses, leap to the same absolute height, each one accomplishes an amount of work which is precisely proportional to its mass. When a man jumps over an obstacle which is two feet high, he accomplishes a work which is twice as great as that of the flea or the grasshopper, which can scarcely jump a foot. These views are illustrated by interesting comparisons between the inhabitants of Lilliput and Brobdingnag, by the rapidity of motion in the wings of insects, and in various other ways.—*Rev. Scientif.*, Jan. 27, 1883. C.

Material Particles in Electric Sparks.—Friedrich Wächter publishes the following conclusions from his experiments: 1. There is a removal of particles from the anode, in atmospheric air, under pressures varying between 4500 and 10 millimeters of quicksilver; the removal of particles from the kathode is observed only under pressures between 63 and ·005 mm. 2. The quantity of particles removed in equal times and under similar circumstances, diminishes at the anode and increases at the kathode with diminishing pressure. 3. The anode particles are carried to a much greater distance than the kathode particles, under the same circumstances (at 63 mm. pressure about 3400 times as far). 4. The anode particles proceed, under all pressures, from a comparatively small surface; the kathode particles are thrown from surfaces which increase with diminishing pressure and are sometimes 10,000 times as great as that of the anode particles. 5. The anode particles always proceed from the portion which lies nearest to the kathode; the kathode particles may go from its entire surface. 6. The projection of anode particles is aided by a curved or pointed form of the electrode; that of the kathode particles by a clean unoxidized surface. 7. The anode particles proceed to the kathode in the direction of least resistance. The movement of the kathode particles is normal to the surface and uninfluenced by the place of the anode or the direction of the current. 8. The anode particles may move in all imaginable curves; the direction of the kathode particles is rectilinear. 9. The anode particles are deflected by a magnet as if they were diamagnetic; the kathode particles as if they were paramagnetic. 10. The anode particles are transported both in luminous and in non-luminous conditions; the kathode particles only when non-luminous. 11. The anode particles have a measurable magnitude and are apparently torn off mechanically; the kathode particles are inappreciably small and appear to be produced by a kind of evaporation. 12. The heating of the electrodes favors the projection of particles from the kathode; the influence upon the anode is somewhat doubtful. 13. The kathode particles facilitate the passage of the electric current from the electrode to the gas molecules; this is not the case with the anode particles. 14. The researches of G. Wiedemann and Kuhlmann show that a greater electric tension is requisite for the projection of particles from the anode than from the kathode. These facts are supposed to show a difference between positive and negative electricity, which is qualitative, and which cannot be explained by the mere excess or deficiency of a single activity.—*Ann. der Phys. u. Chem.*, Nov., 1882. C.

Powdered Asbestos.—M. Erichsen, of Copenhagen, uses powdered asbestos for making a special enamel or coating. The powder is mixed with soluble salts, such as silicate of potash, and mineral or other colors which combine with the silicic acid, so as to form a product which resists the action of oxygen, heat, cold and moisture. This furnishes a refractory glazing, which protects porous materials and which can be applied to wood, to gas or water pipes, to brick walls, to constructions of stone or cement, etc., etc. It has been proposed to use it in boilers, to protect the plates against the too great intensity of the fire. When applied to masonry or to wooden objects, the surface is first washed with water and soap. In the preparation of the coating it is only necessary to use the refuse of the asbestos, which would be worthless for any other purpose.—*Chron. Industr.*, Jan. 21, 1883.

Utilizing Subterranean Heat.—Many methods have been proposed for utilizing the internal heat of the earth, and if we remember that the temperature increases at an average rate of about 1° F. for each 50 feet of increasing depth, it will be readily seen that such utilization is quite possible. It is probable, however, that the excavation of wells, deep enough to boil water and produce steam, would involve a greater cost than the production of steam by the combustion of coal or by solar heat. The Japanese are seriously considering the utilization of the hot springs near Tokio, as a means of producing heat and power. The subject has been discussed in the Japanese Seismologic Society. In a country where the presence of hot springs and the frequency of earthquakes indicate a rapid increase of subterranean temperature, the thing may be quite practicable. It has even been questioned whether the extraction of the heat would not diminish in some degree the frequency and intensity of earthquakes.—*Soc. des Ing. Civ.*, Oct., 1882. C.

Electric Shadows.—P. Riess has published the following laws: An electrized surface shines in the open air, only in the places which have been struck by an oppositely electrified air current. The surface does not shine where the current is interrupted by an interposed conducting body, but there is a shadow of the same form as the interposed body. If the current is not discharged, but only turned aside by a non-conductor, there is usually no shadow; but in feeble machines a small conductor sometimes produces a slight shadow.—*Ann. der Phys. u. Chem.*, Nov., 1882. C.

Electrical Wood Cutting Machine.—Th. Günther, of Zerbst, has patented a wood cutting machine, in which a number of platinum wires are united in a frame and heated by a galvanic battery, so as to be used as saws for cutting logs into boards.—*Dingler's Journal*, December 6, 1882. C.

Homeopathy and Radiant Matter.—The homeopaths claim that medicinal matter when reduced to infinitesimal proportions has special and powerful efficacy; their adversaries ridicule the idea. The experiments of Crookes have shown that radiant matter possesses new properties. An enthusiastic admirer of Hahnemann cites this fact as a strong confirmation of the infinitesimal theory.—*Les Mondes,* April 14, 1883. C.

OBITUARY.—JOHN C. TRAUTWINE.

John Cresson Trautwine, the eminent civil engineer, whose death occurred on the fourteenth of September, 1883, at his home in Philadelphia, was the eldest child of the late William Trautwine, Sr., and Sarah Wilkinson, his wife. He was born in this city March 30th, 1810, and his early childhood was passed at his father's house on Water street, near Market, adjoining that of the late Stephen Girard.

While very young he acquired a marked fondness for the natural sciences, particularly physics and mineralogy. In all probability this inclination was awakened by his father's friends, one of whom, the late Joseph Loughead, Sr., at that time a prominent teacher, took much interest in the boy and encouraged him in various ways. When about seven years old, he one day strolled away from the house and was so long absent that his father began a search for him which ended by his discovery, fast asleep, on a stall in the old Market street market sheds, with his pockets so stuffed with mineral specimens from the adjacent country that he could walk but with difficulty. Soon after this he was placed under the charge of the late James P. Espy, who may be said to have been the father of the system of organized meteorological observations and under whom he studied natural philosophy and mathematics. At an early age he learned to draw and paint with facility and quickly became an adept in water coloring. His rough note-book contains exquisitely painted little sketches of bridges, parts of buildings and other subjects, on the margin of pages crowded with hastily written memoranda.

In 1828, when eighteen years old, he entered the office of the late William Strickland, at that time located on the south side of Arch street, above Sixth, opposite the theatre then being built. Mr. Strickland was the most prominent civil engineer and architect in this part of the United States and young Trautwine, while with him, was engaged on some of the principal engineering works of that day.

Soon after entering Mr. Strickland's office, in 1828, he prepared and submitted a competitive design for the Penn Township Bank, opposite

Franklin Square, at Sixth and Vine streets. His design was accepted and he superintended the erection of the building. He also designed and supervised the placing of the iron-railing around Franklin Square, now in process of removal.

With two of his fellow-students in Mr. Strickland's office he formed an intimacy which continued for years. One was Ellwood Morris, the well-known engineer, with whom in later years, he shared an office in the Franklin Institute building, and the other was Thomas U. Walter, who subsequently became architect of Girard College and of the new Capitol building at Washington.

The Delaware Breakwater was constructed under Mr. Strickland's supervision and Mr Trautwine was for some time engaged on that work. He also assisted Mr. Strickland in the erection of the United States Mint, the Blockley Almshouse and many other prominent buildings.

While in Mr. Strickland's office, it was his duty to exhibit and explain to callers a model railroad section, adapted to cars with flanged wheels. The young and enthusiastic visitors foresaw a practical use for this arrangement, but the older and more conservative detected its visionary character. Here was the beginning—the birth of railroad engineering in America; and it was the destiny of the subject of this memoir to foster its development, by the field-labor of his earlier manhood, and in later life, by his published engineering-works, which may be found in the hands of almost every engineer in the United States.

In 1831 he was engaged on the Philadelphia section of the Columbia Railroad, from the old Columbia, or Peter's Island, Bridge, over the Schuylkill river (a detailed description of which he published in the FRANKLIN INSTITUTE JOURNAL for August, 1834), to Broad street, and in 1832 he laid out Logan Square. He competed successfully for the design of the Moyamensing Commissioners' Hall in 1833, and in the same year, together with the late J. Edgar Thompson, afterwards president of the Pennsylvania Railroad, made a survey for a canal from Fairmount to the mouth of Mill creek, near Gray's Ferry.

In 1835 he was appointed principal assistant engineer on the Philadelphia, Wilmington and Baltimore Railroad. At Havre de Grace, in this year, he became acquainted with the late Benjamin H. Latrobe, of Baltimore, subsequently engineer of the Baltimore and Ohio Railroad, with whom he formed a lasting friendship, and to whom he long afterwards dedicated his principal work on engineering. In 1836 he was appointed engineer of the Philadelphia and Trenton Railroad, on the resignation of Mr. Samuel Kneass; but resigned on receiving, in the same year, the appointment as chief engineer of the Hiwassee Railroad, extending from Tennessee into Georgia. Having married in 1838, Miss Eliza Ritter, daughter of the late Mr. Jacob Ritter, Jr., of Philadelphia, he built a residence in Knoxville, Tennessee, expecting to continue there as permanent engineer of the road after its completion. The various State governments were at that time undertaking extensive measures to open up and develop the wilder sections, and Mr. Trautwine wrote and published an extended article upon the Internal Improvement of the South. The financial disturbances of the period involved the Hiwassee Railroad, which suspended work at the time when the chief engineer, with the president, General Jacobs, were on the eve of constructing rolling-mills to manufacture for the road the first iron rails to be made in this country. Mr. Trautwine left Tennessee and returned to Philadelphia in 1843, having been engaged on the Hiwassee Railroad nearly six years. He next surveyed the route for the Ralston and Blossburg Railroad, in Pennsylvania, and soon after, in 1844, sailed for Carthagena, New Granada, S. A., where, for five years, he was engaged with General George M. Totten in the construction of the Canal del Dique, connecting the Magdalena river with the bay of Carthagena. His extended work here, surmounting all the natural obstacles which a vast tropical swamp could oppose to man's skill and labor, was a fitting preparation for that after-work, with which his name will ever be associated, on the Isthmus of Darien and the Atrato. Returning to the United States in 1849, he surveyed the borough of Germantown, now the Twenty-second Ward of Philadelphia, correcting errors of long standing, and rearranging the lines of many streets, to which he gave their present names. Before the expiration of that year, having been appointed, jointly with General Totten, engineer of the Panama Railroad, he left Philadelphia for the Isthmus of Panama in December, and in January, 1850, began the surveys which finally determined the route of that highway of nations. A writer in *Harper's Monthly Magazine*, for January, 1859, says of this undertaking: "Well might the hardiest projectors have shrunk from attempting its construction. The first thirteen miles, beginning at Navy Bay, were through a deep morass, covered with the densest jungle, reeking with malaria, and abounding with almost every species of wild beasts, noxious reptiles and venomous insects known in the tropics. * * * Further on, the line was through a rugged country, along steep hill-sides, over wild chasms, spanning turbulent rivers and mountain torrents, until the summit ridge was surmounted, when it descended abruptly to the shores of the Pacific Ocean. Mr. Trautwine, after a careful survey of the whole line of Atlantic coast from the mouth of the Chagres to the harbor of Portabello, located the eastern terminus at the island of Manzanilla, on the bay of Limon, or Navy Bay, where the City of Aspinwall now stands, and with Mr. J. L. Baldwin as assistant, began from this point, one of the boldest engineering enterprises ever attempted."

He prepared a map of the Isthmus, a reduced copy of which will be found with a description, in the FRANKLIN INSTITUTE JOURNAL for January, 1871.

Returning from Panama to Philadelphia in 1851, he published, in the same year, the first edition of his "Curves" and "Excavations and Embankments," and in April, 1852, again sailed for the Isthmus of Darien, to seek an inter-oceanic canal route *via* the Atrato river. This stream flows northward through New Granada into the Gulf of Darien, along the base of the western Andes. Humboldt, long before, basing his conclusions on superficial observations and tales of the natives, had hinted at a possible canal route through a hoped-for depression in the mountain chain, by which a short water communication would connect the Atrato river and Pacific Ocean. Mr. Trautwine, having surveyed the Gulf of Darien and the several mouths of the Atrato, ascended that river to its source, diverging to examine its principal tributaries. Crossing the dividing ridge between the Atrato and San Juan, he descended the latter river to the Pacific Ocean, finding the fabled Canal of Raspadura, long believed to exist between the head waters of the two rivers, and through which canoes were said to pass from ocean to ocean, *a hill*, up and down which canoes were dragged in their passage. Having examined the Pacific coast-line bordering the western Andes, he crossed the range at various points, ultimately deciding upon a canal route from the Atrato, at Vigia Curbarador, to Cupica Bay on the Pacific, as the least inadvisable. The cost he estimated at $325,000,000. A detailed report of this survey was published in the FRANKLIN INSTITUTE JOURNAL for 1854, and afterwards in book form, with lithographic illustrations and maps by the author. As a summary he says, in this report: "I have coasted and boated along both sides of the region comprised between the Pacific Ocean (from Panama to Buena Ventura), on one side, and the Caribbean Sea, the Atrato, and the San Juan on the other side; and have crossed it both at the site of the Panama Railroad and at three other points more to the south. From all I could see, combined with all I have read on the subject, *I cannot entertain the slightest hope that a ship-canal will ever be found practicable across any part of it.* When I employ the word *practicable* it is meant in a practical sense."

Of this survey, Admiral Davis, in his Report on Interoceanic Canals and Railroads, made in 1867, to the Secretary of the Navy, states that subsequent explorations have confirmed both the details and general results.

Mr. Trautwine next examined and reported upon the harbor of Arecibo, in Porto Rico, after which, and until 1855, he acted as engineer of the Coal Run Railroad, in northeastern Pennsylvania. His right arm was crushed between two iron coal-cars, of new design, which he was examining at Port Richmond, when the accident occurred. The loss of his arm, however, did not materially interfere with his surveys, literary work, or even his designing and art-work. Claiming that power resided in the mind rather than in the member, and that the will and intelligence of the former should soon teach an unaccustomed intrument to excute its purposes, he demonstrated, by his after-work, the correctness of his view.

In 1856 he surveyed the Lackawanna and Lanesboro Railroad in northeastern Pennsylvania. In 1857 he again left the United States for Honduras, where he surveyed the route for an inter-oceanic railway, passing through Comayagua, the capital. This survey was completed the following year. War in the United States, a year later, interfered with the further progess of this enterprise, which some time afterward interested the late Emperor Napoleon III, but was never executed.

In 1858, by invitation of Sir John A. Macdonald, Premier of Canada, he examined and reported upon the harbor of Montreal, with a view to its increased adaptability as a port of entry, arranging a new system of docks for that city. In 1864 he planned a harbor for Big Glacé Bay, Nova Scotia, and soon afterwards reported upon a system of water-supply for Rochester, New York.

After this time he occasionally acted as consulting engineer, or testified as an expert, when engineering questions were involved, but otherwise retired from the active duties of his profession, devoting himself to study, the investigation of abstract engineering problems, and the constant revision of his published works. In 1871 the first edition of the "Engineers' Pocket Book" appeared. This work, which was the product of a life coeval with the development of modern engineering science, immediately received the favor of the profession; more than twenty thousand copies having been issued since that date. Several years since, he associated with himself, in the work of revising his publications, his son, John C. Trautwine, Jr., and within the past year practically yielded to him the task which was manifestly growing too great to continue. His health had been growing worse for a long time, and since the spring of 1883 he suffered from extreme and gradually increasing prostration, superinduced, without doubt, by excessive exposure in his earlier life. He continued at work, however, until within two weeks from the time of his death, growing weaker from day to day, but striving, to the last, to effect by will and ingenuity, the loss of physical vitality. During the night, two days before he died, he asked, toward morning, "What time is it?" His son told him the hour, and he replied, "The steamer—the steamer from Aspinwall—our passage—from New York." A few moments later he exclaimed, "Honduras—Europe—Europe!" his mind in these last hours, mechanically retracing the eventful periods thirty years past. He died quietly, and apparently without pain. His widow survives him, with two sons, William Trautwine, conveyancer, and John C. Trautwine, Jr., civil engineer; his only daughter, Mrs. Susan R. MacManus, having died two years previously.

Mr. Trautwine was a member of the Franklin Institute, the Academy of Natural Sciences, the American Philosophical Society, the Historical Society and other learned bodies, and frequently contributed to their publications, and to other journals, articles on technical and scientific subjects.

As a mineralogist he was widely known, and enjoyed the friendship of Dana, Brush, Rand, Roepper and others eminent in this science. His collection of mineral specimens was one of the most unique in this country.

Whether, in future years, his reputation will rest mainly on his explorations or his writings, cannot now be determined. Through each, he attained a world-wide celebrity. He was the first man to supply both accurate and comprehensive knowledge of the Isthmus of Darien. All subsequent explorers refer to his work, confirming its results; and it is probable that, a century hence, his name will be as closely identified with schemes of inter-oceanic communication as it is to-day. His published writings, on the other hand, are the text-books of the engineering profession; his name being related to it as that of Gray to botany, or Dana to mineralogy; and, under the editorial care of his son, who was favored with his special instruction, the present standard of his "Pocket Book," and other works, will doubtless be maintained.

At the close of this review of a varied and pre-eminently useful life, it will suffice to say that, at the time of his death, which occurred at the age of seventy-three years, Mr. Trautwine stood in the foremost rank of his profession.

Tho. U. Walter,
Jos. M. Wilson,
Fred. Graff.

Franklin Institute.

[*Proceedings of the Stated Meeting, held October* 17, 1883.]

Hall of the Institute, Oct. 17, 1883.

The meeting was called to order at the usual hour, with the President, Wm. P. Tatham, in the chair. There were present 71 members and 17 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting of the Board, held Wednesday, October 10th, 6 persons had been elected to membership. He also reported the minutes of the several standing committees. There were no reports of special committees, and no papers announced.

The Secretary's report embraced some remarks on Professor S. P. Thompson's recent work, advocating the claims of Johann Phillipp Reis, to be recognized as the first discoverer of the electric transmission of speech, and the inventor of devices and instruments corresponding in their construction and objects with those now used in what is known as the Bell system of telephony; a description of the electrical railway system of Mr. Leo Daft; and an abstract of the impending changes in the British Patent Law.

A specimen of the "Compound Wire" of the Postal Telegraph Company of New York was shown and described. It consists of a steel wire core weighing 200 pounds to the mile and having a tensile strength of 1650 pounds, on which copper is deposited by the electroplating process to any desired thickness. At the present time, the factory at Ansonia, Conn., has in use for the purpose, twenty-five large dynamo machines, depositing about 10,000 pounds of copper per day. The copper is deposited uniformly over the whole surface of the steel wire, the latter being passed slowly and continuously through the depositing solution, the time required from its entrance to its emergence as finished "compound wire" being 60 hours, in which time a copper deposit is obtained equivalent in weight to 500 pounds per mile. On the present scale of working about 50 miles of the wire are in the solution at all times. The compound wire is claimed to have a number of advantages over the iron wire now in use for telegraphic purposes, of which the more noteworthy are—much greater conductivity, greater tensile strength, greater durability, cheapness as to first cost and maintenance as compared with iron wire of the same conductivity, and low resistance, enabling fewer cells of battery and currents of very low tension to be used, and insuring uninterrupted communication in all kinds of weather.

An improved gasoline lamp for the use of plumbers and others requiring a portable flame for melting, soldering, and kindred work, was also shown on behalf of Mr. Ingram, of Philadelphia.

Dr. I. Kitsee, of Cincinnati, was then invited to describe his Automatic system for the Detection of Fire-damp in Coal Mines by electrical means.

Dr. Kitsee made some introductory remarks bearing on the importance of some reliable automatic means of detecting the presence of explosive gases in mines, to prevent the frequent recurrence of explosions and calamitous loss of life, and then proceeded to describe his system, as follows:

"The working of this detector or indicator is very simple. A metallic box of which two sides are covered with fine wire gauze is enclosed in another metallic box somewhat larger, with the same wire gauze on the same sides. A clockwork is placed between the walls of these two boxes. A fine silken thread attached to the clock-spring is drawn across the inner box and fastened on the opposite wall of the same, holding the whole clockwork in check. The same clockwork has also a wheel with spurs arranged in such a way that the striking of the same on a small metallic plate connected with a wire leading from a battery, will close a broken circuit, as the wheel itself is connected with the other wire of the same battery. A common electric bell will then at each striking, sound the alarm. The spurs or points of this wheel are in each apparatus differently arranged to strike different numbers, just as in the common fire alarm apparatus. The platinum ends of two needles connected with another battery, are placed in the centre of the same box in juxtaposition to each other. If now an electric current is sent through the last circuit wires, strong enough to produce a spark between the two platinum points and at the same time there happens to be an explosive mixture of the fire-damp in the box, so that an explosion occurs and the silken thread is burned in consequence, the clockwork is set in motion and by making and breaking the other circuit indicates the place from whence the alarm comes.

" As to the placing of the apparatus I would only say that the box or boxes, as the case may be, shall be placed in different parts of the mine, at intervals of 300 feet in each gallery, securely fastened to the roof; to the roof for this reason, because, as is well known, the gas being lighter than air, may already have accumulated in dangerous quantities in the upper parts before any appreciable quantity can be found on the lower levels.

"The wires leading to and from the boxes are placed in a leaden tube or pipe, not only to prevent accidents to, but also from the same.

"The alarm-bell and batteries, as also the indicating board, are placed in the office of the superintendent. Every morning before the miners descend to their work, the superintendent sends an electric current through the above-described wires; if now, as an answer, the alarm apparatus sounds, he will know that an explosion has occurred in one of the boxes, and at the same time know in which box and in what part of what gallery. He will not allow the men to resume work ere that part of the gallery has been purified by means of the air-pump or by the other methods well known to miners. Should no answer follow, he may rest assured that his laborers will be as safe in the coal mine as in the best ventilated work-shop."

An exhibition of the working of the apparatus was given at the close of the speaker's remarks.

Some remarks were presented by Mr. Wm. J. Gregory, of Philadelphia, on the subject of subways in cities, which he illustrated by means of lantern projections of a number of views of notable structures of this kind in European cities, especially in London. Mr. Gregory clearly set forth the growing necessity of such subways in all large cities, in view of the multiplication of underground pipes for various forms of service (sewerage, gas and water distribution, steam heating, electric conduits, etc.), and in view of the inconvenience and obstruction to traffic resulting from the frequent tearing up of streets for the laying of new lines or the repair of old ones.

Under the head of Deferred Business, the report of the "Joint Committee on the Reading of Papers" was called up for disposition. After some discussion, final action thereon was postponed until the November meeting, and it was made the special business of that meeting.

Under New Business, Mr. J. W. Nystrom offered the following preamble and resolution, viz.:

To the President and Members of the Franklin Institute.

WHEREAS, The City of Philadelphia has suffered a great many disastrous steam boiler explosions which could have been prevented by proper precautions, and

WHEREAS, There are now in use in the City of Philadelphia some six hundred boilers which have dangerous flat cast iron heads, and that either one of them is liable to explode at any moment if in charge of incompetent attendants, and

WHEREAS, Such a great number of dangerous steam boilers cannot reasonably be removed without great inconvenience and expense to the owners of these boilers, and

WHEREAS, It is known that the explosions of this class of boilers have been caused by incompetent attendants, be it

Resolved, That the Mayor and Select and Common Councils of the City of Philadelphia be respectfully requested by the Franklin Institute to pass an Ordinance to the following effect, viz.:

Supplement to an Ordinance of July 13, 1868, *entitled an Ordinance regulating the Inspection of Steam Boilers in and for the City of Philadelphia, Pennsylvania.*

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain*, That from and after the 1st day of January, 1884, all engines and steam boilers operated in the City of Philadelphia shall be run and in charge of only such engineers as shall be furnished with a proper certificate as hereinafter provided.

SEC. 2. The Chief City Inspector is hereby authorized and required to designate the time and place when and where all applicants for a certificate shall be entitled to apply for examination and shall receive a certificate if found to be competent. For this purpose the said Chief Inspector shall sit at least once a month.

SEC. 3. He shall issue certificates of two classes—the first to such parties as may in his judgment be qualified to have charge of an engine and boilers, the second, to such as may in his judgment be qualified to have charge of steam boilers in establishments where no engine is used.

SEC. 4. For these certificates, which shall be issued for one year, each party receiving the same shall pay a fee of two dollars for first-class and one dollar for second-class certificate.

SEC. 5. That the said City Inspector shall refuse to grant a certificate of inspection to any person who shall maintain or keep in use or operation, or shall put in use or operation, any stationary steam engine or boiler within the said City of Philadelphia, which shall not be in charge of an engineer duly furnished with an engineer's certificate as aforesaid.

SEC. 6. That whenever the said City Inspector shall learn of any boiler or engine being operated otherwise than by an engineer duly qualified and furnished with a certificate as aforesaid he shall forthwith cancel and revoke his certificate of inspection. And the certificate of inspection of any steam-user who shall thus attempt to operate an engine or boiler without the care of an engineer furnished with a proper certificate shall be deemed and adjudged forfeited, and such steam user shall be subject to all the pains and penalties provided by Act of Assembly of May 7, 1864.

JOHN W. NYSTROM.

On motion of Mr. Nystrom, the preamble and resolution were referred to a special committee. The President appointed Messrs. J. W. Nystrom, Washington Jones, C. M. Cresson, Coleman Sellers, Jr., Thomas Hockley, Esq.

Mr. Samuel Sartain, on behalf of Mr. Thos. U. Walter, offered the following resolutions, which were adopted without dissenting voice, viz.:

"*Resolved*, That the members of the Franklin Institute have heard with deep regret of the death of their eminent associate, JOHN C. TRAUTWINE, of Philadelphia; also,

"*Resolved*, That, in view of his high professional standing, his long association with the Institute, and his personal worth, a committee be appointed to draft a memorial of the deceased, and that the same be published in the JOURNAL."

The President thereupon appointed as a committee to draft such a memorial, Messrs. Thos. U. Walter (Chairman), Fred'k Graff, and Joseph M. Wilson. Adjourned.

WILLIAM H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVI. DECEMBER, 1883. No. 6.

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THE CHEAPEST POINT OF CUT-OFF.

By WILLIAM DENNIS MARKS,

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Let (HP) = the desired horse-power of the engine.

Let P = the mean effective pressure of steam in cylinder in pounds per square inch.

Let P_b = the absolute initial pressure of steam in pounds per square inch.

Let B = the absolute back pressure of steam in pounds per square inch, exhaust open.

Let e = the fraction of the volume at which steam is cut off.

Let C = the constant charges on engine and boilers in dollars and cents.

Let c = the fraction of the volume of steam used in any convenient period equivalent to the value of the constant charges.

Let b = the fraction of the volume of the steam at which exhaust closes being measured from the opposite end of the cylinder from which e is measured.

Let k = the fraction of the volume of the steam allowed for clearance.

Let V = the volume of the steam cylinder, inclusive of clearance.

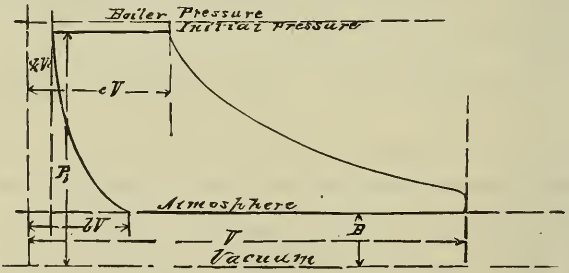
We can then write the following equation:

$$y = \frac{\text{Work}}{\text{Cost of work}} = \frac{\text{Mean effective pressure} \times V}{\text{Cost of steam} + \text{constant charges} - \text{Value of steam saved by compression}} \qquad (1)$$

This equation, having for its denominator values in dollars and cents, must be rendered homogeneous.

Since money and steam are convertible, we will take the denominator in volumes of steam.

The best method of obtaining the volume of the steam cylinder (V) and the clearance (k) is to fill the cylinder with water with the crank on the most distant dead point, and then to fill the clearance with water. The weight of water in the clearance, divided by the weight of water in the whole cylinder and clearance, will give the value of k. Reference to the diagram will make this clear.



The mean effective pressure $= P = eP_b \left[1 + \text{nat. log. } \frac{1}{e} - \frac{k}{e}\right]$
$- B\left[1 - b\left(1 - \text{nat. log. } \frac{b}{k}\right)\right]$

For a cut-off e the water used per horse-power per hour is approximately $W =$

$$\frac{859375\ e}{S\left\{eP_b\left(1 + \text{nat. log.} \frac{1}{e} - \frac{k}{e}\right) - B\left[1 - b\left(1 - \text{nat. log.} \frac{b}{k}\right)\right]\right\}} \quad (2)$$

in which $W =$ weight of water evaporated, and $S =$ specific volume of the steam for the pressure P_b.

To find the money value of the steam used we must multiply this value of W by the horse-power, by the number of hours per day the engine is used, and by the cost of steam (*i. e.*, coal and water) per pound.

Equation (1) can be written as follows:

$$y = \frac{PV}{\left[e + c - b\,\frac{B}{P_b}\right] V} \qquad (3)$$

for the period of one stroke, and, since the engine can be assumed to make its strokes uniformly, it is equally true for any period of time.

To deduce the value of c, we can write, for the cost of the steam, from equation (2), $W_1 =$

$$\frac{eD}{eP_b\left\{1+\text{nat. log.}\frac{1}{e}-\frac{k}{e}\right\}-B\left\{1-b\left(1-\text{nat. log. }\frac{b}{k}\right)\right\}} \qquad (4)$$

in which the constant $D = \dfrac{859375}{S}$ (HP) × hours × price of steam per pound.

We then can write the following proportion :

$$c:e::C:\frac{eD}{eP_b\left\{1+\text{nat. log. }\frac{1}{e}-\frac{k}{e}\right\}-B\left\{1-B\left(1+\text{nat. log. }\frac{b}{k}\right)\right\}}$$

Therefore $c =$

$$\frac{C}{D}\left\{eP_b\left[1+\text{nat. log.}\frac{1}{e}-\frac{k}{e}\right]-B\left[1-b\left(1+\text{nat. log.}\frac{b}{k}\right)\right]\right\} \qquad (5)$$

Equation (3) then becomes

$$y=\frac{eP_b\left[1+\text{nat.log.}\frac{1}{e}-\frac{k}{e}\right]-B\left[1-b\left(1-\text{nat.log.}\frac{b}{k}\right)\right]}{e+\frac{C}{D}\left\{eP_b\left[1+\text{nat. log. }\frac{1}{e}-\frac{k}{e}\right]-B\left[1-b\left(1-\text{nat. log. }\frac{b}{k}\right)\right]\right\}}-b\,\frac{B}{P_b} \qquad (6)$$

Differentiating this equation with respect to e, and seeking a maximum, we have

$$e=\frac{B\left[1-b\left(1\ \text{nat. log. }\frac{b}{k}\right)\right]}{P_b}+k-b\,\frac{B}{P_b}\,\text{nat. log. }\frac{1}{e} \qquad (7)$$

Giving a result independent of the constant charges, and dependent only on the initial pressure, the back pressure, and the clearance. It will be observed that the curve of expansion used is the equilateral hyperbola. This curve coincides, with great accuracy, with the best results derived from indicator diagrams, and we can therefore safely use it until an adiabatic engine is produced for our discussion.

If equations (4) be accurately written

$$W = \frac{\left[e - \frac{Bb}{P_b}\right] D}{P}$$

and used in the following work, we would have the value of *e* increased by the following numerically small quantity :

$$\frac{C \quad Bb \quad \left\{ eP_b\left[1 + \text{nat. log. } \frac{1}{e}\right] - P_b k - B\left[1 - b\left(1 - \text{nat. log. } \frac{b}{k}\right)\right]\right\}^2}{D \left[e - \frac{B}{P_b}\right]^2 \quad P_b^2}$$

Since, however, the quantities in the numerator are all small and the quantities in the denominator give a relatively very large product, we can neglect this term without sensible error. The quantity $\frac{Bb}{P_b}$ is quite small in a non-condensing engine *and can never exceed the clearance k in value.* In a condensing engine it is usually very much smaller. In making close calculations of the water used we cannot afford to neglect this quantity, but it does not sensibly affect the point of cut-off.

The usual and "proper" thing among many of the writers of the present day is to dismiss the isothermal curve with a condemnation and to make use of the adiabatic curve, but unfortunately for this curve it does not agree so well with the actual curve of pressures from our best engines as taken with an indicator, as does the isothermal curve.

If we assume no clearance and no compression, equation (7) becomes

$$e = \frac{B}{P_b} \qquad (8)$$

A law first stated by the writer in the JOURNAL OF THE FRANKLIN INSTITUTE, June, 1880.

The use of equation (7) will be found to give practically correct points of cut-off for non-condensing engines.

A consideration of equation (2) will reveal why it is not possible to carry out this law to its finality in the case of condensing engines.

It is not possible to construct an engine without clearance, or to obtain a perfect vacuum; but if, for the purpose of obtaining an extreme limit, we neglect these, equation (2) becomes

$$W = \text{constant} \times \frac{1}{1 + \text{nat. log. } \frac{1}{e}} \qquad (9)$$

If in this we substitute successive values of e, we obtain the successive percentages of water used per horse-power per hour.

$$\text{For } e = 1 \quad \frac{1}{1 + \text{nat. log. } \frac{1}{e}} = 1{\cdot}00$$

$$\text{For } e = \tfrac{1}{4} \quad \frac{1}{1 + \text{nat. log. } \frac{1}{e}} = 0{\cdot}42$$

$$\text{For } e = \tfrac{1}{8} \quad \frac{1}{1 + \text{nat. log. } \frac{1}{e}} = 0{\cdot}32$$

$$\text{For } e = \tfrac{1}{9} \quad \frac{1}{1 + \text{nat. log. } \frac{1}{e}} = 0{\cdot}31$$

The gain by increasing the expansion from eight to nine times is but a theoretical one per cent. at the outside, and possibly there is an actual loss.

In "The Limitations of the Steam Engine," JOURNAL FRANKLIN INSTITUTE, August, 1880, the writer stated as the law of the economical use of steam for $e = \frac{B}{P_b}$

$$W = \text{constant} \times \frac{1}{\text{com. log. } \frac{1}{e}} \qquad (10)$$

Under this condition, expansion can probably be carried farther in non-condensing engines perhaps as high as $e = \frac{1}{12}$ to $\frac{1}{14}$. This does not predicate that less steam per (IP) per hour will be used, as will be seen from equation (2).

Regarding condensation, much yet remains to be determined. Perhaps it is not such a gigantic obstruction to progress as we have been led to believe. The pressing need of the present is an intelligently conducted series of experiments on internal condensation in the steam cylinder.

The principles here enunciated apply with equal force to all classes of engines, which can only differ in the amount of condensation, and in their percentage of useful effect.

Mr. Hill's admirable record of the competitive tests made at The First Miller's International Exhibition, Cincinnati, 1880 would show great leakage past the valves and the pistons of the engines of the makers who then exhibited.

The diagrams show the initial pressure before the cut-off was reached to fall so rapidly as to force us to assume the initial pressure to be sustained up to expansion and to compute the value of e.

This can be done by means of formula (2) which gives, when accurately written,

$$\frac{WSP}{859375}+\frac{Bb}{P_b}=e \qquad (11)$$

or can be deduced from the mean effective pressure.

$$e=\frac{P+P_bk+B\left[1-b\left(1-\frac{b}{k}\right)\right]}{P_b\left(1+\text{nat. log.}\,\frac{1}{e}\right)} \qquad (12)$$

The values of all the quantities in the latter formula can be formed with practical accuracy from the diagram and engine save e and this can be fixed approximately from the diagram for a first log and the successively nearing values used until the desired accuracy is reached. Logarithms do not vary rapidly so the approximations will be few in cases demanding great accuracy. If by o we denote the percentage of the volume at release we have

$$P=e\,P_b\left(1+\text{nat. log.}\,\frac{o}{e}-\frac{k}{e}\right)-B\left(1-b\left[1-\text{nat. log.}\,\frac{b}{k}\right]\right) \qquad (13)$$

The indicator diagram if it can be relied upon would show, in the present case at least, that to neglect o would not introduce so great an error as to use it.

The values of W as given in the table are Mr. Hill's values corrected for the differences in the quality of the steam.

The current practice among engineers of using the terminal pressure to determine the specific volume of steam must necessarily introduce great errors, because the specific volume of steam at low pressures varies enormously for very slight changes of pressure, and a very small error of either the instrument, or of measurement, will greatly alter the result.

The best experimental method of fixing the point of cut-off is to place an indicator on the steam-chest. A sudden jog in the line will mark the points of opening and closing the steam valves.*

We can then use S for the initial pressure with much less probability of error in the results.

The mean effective pressure can be calculated in the usual way, or taken from the diagram.

Mr. Hill states that "The steam per hour by the diagram is the weight of steam to release less weight for steam retained for cushion."

If, however, we make the calculation of steam at initial pressure, we have, as already stated

$$W = \frac{\left(e - \frac{Bb}{P_b}\right) \times 859375}{SP} \qquad (14)$$

The following summary is taken from Mr. Hill's Report, and is only changed in form so as to render the application of the formulæ convenient.

	CONDENSING TRIALS.			NON-CONDENSING TRIALS.		
	Reynolds Corliss.	Harris Corliss.	Wheelock.	Reynolds Corliss.	Harris Corliss.	Wheelock
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Barometer................	14·56	14·47	14·31	14·58	14·47	14·44
P_b Initial press., ab.	105·65	104·55	102·40	104·57	103·99	102·94
Back pressure, abs...	4·45	3·35	4·71	15·33	14·89	15·40
Mean effective pres..	35·40	35·67	33·94	29·78	28·94	29·36
Wt of st pr HP pr hr	14·067	13·755	13·762	17·420	17·220	19·674
Specific volume........	255·07	257·49	262·28	257·49	258·70	260·90
Ind. H. P..................	162·99	165·58	158·38	137·02	134·29	139·97
Clearance..................	·0258	·0189	Exp ·023 Com ·014	·0258	·0189	Exp. ·023 Comp. ·014
Exhaust closes.........	·08	·1382	·0552	·1065	·1365	·0968
Exhaust opens.........	·952	·922	·935	·956	·952	·956
e.. Mr. Hill's. From diagram...	·150	·144	·157	·185	·157	·194
e.. Calculated from formula 11........	·151	·151	·147	·171	·170	·190

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* Suggested by J. Sellers Bancroft.

It will be noted that the order of rating in economy of weighed steam from the boilers at the trials of Mr. Hill is precisely that given by the computed values of e.

It will further be noted that the engine having the lightest load, and consequently the earliest cut-off was the one awarded the greatest economy of steam in the several trials, noncondensing and condensing.

The excess over the others of $\frac{26}{100}$ of an inch in the bore of Mr. Wheelock's engine was not an error which diminished the probability of great economy of steam, but the fact of its having the heaviest load and the least initial pressure in the non-condensing trial brought the economy of the engine below that of the others, although this engine was awarded the greatest economy in the condensing trial in which it had the lightest load and the earliest computed cut-off, but not the was greatest initial pressure. The Harris-Corliss, for the same reasons, was awarded the greatest economy for non-condensing. These points are of value as bearing directly on the question of increase of economy with greater expansions.

The value of e giving greatest economy of steam under the assumptions as to the expansion and neglecting o can be computed from equation (7), and the water per HP per hour can be computed from *Eq* (14).

TABLE OF LIMITING MINIMUM VALUES—COMPUTED.

	CONDENSING.			NON-CONDENSING.		
	Reynolds Corliss.	Harris Corliss.	Wheelock	Reynolds Corliss.	Harris Corliss.	Wheelock
Minimum cut-off, e_0	·059	·042	·069	·151	·139	·160
Minimum mean eff. pressure, P_0..........	16·53	12·51	18·25	26·45	24·67	27·47
Minimum weight of water per H.P. per hour, W_0..................	11·22	10·14	11·97	16·83	16·80	17·50
Minimum H.P........	above 75	above 46	above 95	119·	116·5	131·

All of these calculations have been made under the assumption that the steam weighed from boilers is all accounted for by the diagram, which is not absolutely true, but would seem from Mr. Hill's results to be proportionally true with a close approximation, since the proportion of weighed steam [calculated from volumes of water] was to the steam shown by the indicator as 4 to 3 or thereabouts for both condensing and non-condensing engines.

These experiments are utterly valueless for the purpose of determining the amount of condensation, since these engines, presumably made with all the care and skill of experienced makers, leaked so badly when warmed up that the clearance could only be gotten approximately.

In the matter of the proportion of water accounted for by the indicator, we should have a series of experiments conducted with every precaution observed by Mr. Hill, but the steam pressures should be varied through a wide range.

For each steam pressure the point of cut-off should be varied throughout the stroke at regular intervals of say one-tenth or less, and of course, the load with it. In fact it would perhaps be best to use an automatic cut-off and vary the load, leaving to it the adjustment of the cut-off.

The thermal values of the steam must be most scrupulously determined at the boiler, at the steam-chest and at the exhaust.

Leaks at the piston could be almost perfectly prevented by simple temporary precautions as to the piston packing during the experiments.

Finally, each set of experiments should be made sufficiently long to eliminate accidental errors. Particular attention should be paid to the indicator, as its errors are sometimes greater than would be believed when in good (?) working order, and when out of order, or in any way dirty, it is utterly valueless. Something better than any of our present indicators must be devised to be of any accurate scientific value or to obtain the faith of any one save for rudely approximate work and for everyday practice in steam engine designing.

Fortunately this difference of actual and indicated steam does not affect the point of cut-off materially in most cases. The exception may arise with great compression.

The actual conditions as to back pressure (B), clearance (k), and compression (b) are not altered in the last computations.

The results in the last table are obtained by the use of the following formulæ :

$$B_1 = B\left[1 - b\left(1 \text{ nat. log. } \frac{b}{k}\right)\right]$$

$$e_0 = \frac{B_1}{P_b} + k - \frac{bB}{P_b} \text{ nat. log. } \frac{1}{e_0}$$

$$P_0 = P_b\left[e_0 + e_0 \text{ nat. log. } \frac{1}{e_0} - k \right] - B_1$$

$$W_0 = \frac{859375\left(e_0 - \frac{Bb}{P_b}\right)}{P_0 S}$$

Minimum and cheapest horse power $= \frac{P_0}{P} \times$ Indicated HP.

The dimensions b and k are more accurately taken from the engine than from the diagram, which, while giving a good average, is rarely exact at any particular place.

The theoretical minimum results for condensing trials are not closely calculated because they do not surely indicate accurate attainable results, but serve merely to show in what direction progress must be made.

Right here our knowledge is deficient, and we must have more data regarding condensation before attempting to accurately predict real results at high expansions.

Concentration of power is lost with increasing economy of steam. It is a very important attribute of the steam engine, bearing directly upon its efficiency as a machine.

Mr. Hill's experiments on the condensing engines prove most conclusively, within the narrow limits as to expansion which he set by his conditions of trial and size of engine cylinders, that increased expansion meant increased economy of steam. Even with the slight variations of load and steam pressure which he could hardly have prevented, his award as to economy of steam was a matter of chance.

It is not worth while to reopen a much disputed question by making the proper correction so as to show which really was the most economical engine.

With the method of testing used, without corrections, any one of these evenly-matched engines could have apparently shown itself the superior with slightly favoring conditions or variations in the load or the initial pressure.

The influence of compression and clearance and of condensation may be discussed in a future paper.

Those interested in condensation and its causes should read the researches of M. Hirn, translated by Prof. Smith, in the *Journal of the Association of Engineering Societies,* Nos. 1, 8, 9, 10 and 11, of Vol. I, and Nos. 3 and 7 of Vol. II.

It is to be regretted that no readily applicable law of the condensation has been developed by his work. One point is clear, a very large condensation usually occurs with saturated steam.

In closing this already too long paper, we would add that we do not wish to create the impression that Mr. Hill has omitted any known precautions or has been lacking in skill or vigilance. It is the great superiority of his records, and his careful attention to every detail, that has enabled us to verify our own mathematical investigation of the physical action of steam. The writer is under very great obligation to him.

Philadelphia, November 6, 1883.

EXPERIMENTS UPON NON-CONDUCTING COVERINGS FOR STEAM PIPES.

By Prof. John M. Ordway, Boston, Mass.

[Read before the American Society of Mechanical Engineers, November, 1883.]

In undertaking an investigation of steam pipe coverings it was necessary, in the first place, to decide what method or methods should be used for determining their efficiency as non-conductors of heat. I have met with no recorded experiments of which the details are given in full, but it seems that, in general, two modes have been heretofore employed. In one—the air chamber method—a portion of the covered pipe, while in use, is inclosed in a small box so as to form a close chamber into which the bulb of a thermometer is inserted. The inverse ratio of the temperatures indicated by the thermometer in different trials is supposed to show the relative excellence of the different coverings.

In the second, or condensation method, the steam is allowed to pass from the main pipe out into a side branch covered with the substance in question, and so arranged that whatever water is formed in an observed number of minutes may be drawn off from time to time and weighed or measured. The water is reckoned as having parted with as much latent heat as is contained in that weight of dry steam.

As to the air chamber method, it might be thought easy to carry out, but it is difficult to fit a box of any kind so closely to the covering that there will be no circulation of air into and out of the inclosed space. Of course, a lack of tightness will fatally vitiate the experiment. Again, a box surrounding the pipe and covering, presents a large radiating and cooling surface as compared with the covering itself; and there is no ready way of determining the amount of this continual radiation which increases with the temperature of the air within the chamber. There is no perfect non-conductor wherewith we can surround the air chamber, so as to confine therein all the heat received. If we could prevent all outward radiation, the cavity would sooner or later acquire the temperature of the steam in the pipe, and all coverings would finally give the same results. The only way to make useful observations would be to start with everything cold, and find the time required to raise the air in the chamber to a given temperature. This is, however, hardly practicable.

We cannot obtain absolute or quantitative results by this method, and the comparative figures require indeterminable corrections. Still it was thought advisable to try this plan among others, and see how far the results would correspond to those found by more definitive modes. Accordingly, an apparatus was devised and used for this purpose, consisting of pieces of white pine plank, squared and rabbetted at the ends, to which wooden braces were firmly screwed on. A two-inch tube was bored from the inner side, two-thirds through, to form a cylindrical chamber. The inner side was then planed out so that the concavity, when properly lined should exactly fit the covering to be tried. A hole was bored from the top edge into the cylindrical chamber, and concavity and chamber were both lined with a thick woolen blanket.

When used for testing, the halves are clamped on the pipe-covering with four iron rods and tightened to a close fit with thumb nuts. Thermometers are let down into the chambers, a little cotton wool being crowded in around the stems, to prevent the ingress of cold air.

The two chambers so applied serve to check each other; for if the thermometers differ much, there is a defect in the adjustment. A difference of two or three degrees, however, may occur, on account of an inequality in the two sides of the covering itself.

The condensation method is indirect, and therefore a little uncertain. It necessarily assumes that the pipe is all the time filled with dry steam. But we can hardly expect to have pure steam when its generation is going on rapidly, and the vapor passes off through a long pipe which is all the time radiating heat. We can justly expect only a mixture of real steam with more or less mist. And if this mist, which has already lost its 500° C. of latent heat, is reckoned as invisible steam, our figures will not give the exact truth.

And then again, besides the two or three feet of pipe with the covering to be tried, there are necessarily the cap and other fittings which will lose heat in spite of any wrapping that we may put around them. The gross results, therefore, need to be corrected by the amount due to the condensation by that portion of the branch which is not protected by the covering. It is quite possible to find the amount of this correction, if one has the material of the covering so that he can apply it himself and make it uniform. Thus we may cover, say three feet of pipe, wrap the fittings with a good non-conductor, and make trials enough to get a fair average. Then we may cut off one foot of the pipe and covering, keeping the other parts and their wrappings exactly the same as before, and make a second series of trials. Now, let x be the amount of condensed water due to the three feet of coating, and y that due to the fittings. Having found for one hour $x + y = a$, by the first trials, and by the other set $\frac{2x}{3} + y = b$; by combining these equations we get $x = 3\,(a—b)$; and $\frac{x}{3} = a—b =$ condensation per foot per hour.

If cutting the pipe is not feasible, the deduction to be made may presumably be ascertained in another way. First, determine the whole condensation by the covered pipe and the well wrapped fittings. Secondly, strip off the covering and try the naked pipe with the wrapped fittings. Thirdly, wrap the pipe just like the fittings and make more trials. Lastly, strip off the wrappings from pipe and fittings and try all naked.

Now let $x =$ the amount of condensation by the naked pipe alone; $y =$ that by the naked fittings; $z =$ that by the wrapped pipe alone; $w =$ that by the wrapped fittings; and $u =$ that by the covering in question.

By the last determination above mentioned we have found $x + y = a$; by the second, $x + w = b$; by the first, $u + z = d$; and by the third, $z + w = c$. We may fairly assume that $x : y :: z : w$, or $xw = yz$. Then by the various eliminations and substitutions, we have

$$x = \frac{a\,(b - c)}{a - c}\,;\ y = \frac{a\,(a - b)}{a - c}\,;\ w = \frac{(a - b)\,c}{a - c}\,;\ z = \frac{(b - c)\,c}{a - c}\,;$$

$$u = d - \frac{(b - c)\,c}{a - c}$$

In an actual trial, the result of which is given in No. 25 of the appended table, the slag wool enclosed in straw board, supported by plaster rings at the ends, made altogether a covering 21 inches long. The extra pipe and the fittings were well wrapped with cotton wool, and the condensation was found $d = 108{\cdot}6$ grams per hour. Removing the slag wool covering, it was found that $b = 354$ grams. Replacing the covering by cotton-wool wrapping, it appeared that $c = 105{\cdot}3$ grams. With all wrappings stripped off, it proved that $a = 428$ grams.

Hence, by substituting these values in the above formulæ, we find $x = 316{\cdot}7$; $y = 111{\cdot}3$; $w = 27{\cdot}3$; $z = 77{\cdot}7$; $u = 81{\cdot}3$. Then $\frac{12}{21} \times 81{\cdot}3 = 46{\cdot}5$ grams per foot per hour.

[For making trials by condensation, the author showed drawings of, and described an arrangement, consisting of the mean steam pipe; a T by means of which the steam may pass freely through the nipple, and an elbow into a branch pipe with its covering. A bit of India rubber tube, attached to a stop cock connected with a cap, allows the condensed water—when the cock is opened a little—to pass into a glass flask without direct exposure to air currents. All of the uncovered parts of the branch pipe are wrapped with cotton wool. The angle of inclination is such that whatever condenses in the elbow runs back into the main pipe, unless it remains suspended as mist, and is swept forward.]

As to the question of mist, I see no way of settling it except by combining the condensation method, including the correction given above, with the calorimetric method now to be described.

The calorimetric method, besides being direct and absolute, seemed to me to promise a closer approximation to the truth than any plan used hitherto. To carry it out, a contrivance, specially devised by the author, was provided of different sizes to suit different coverings.

[There was shown a transverse section of the pipe, covering and a pair of calorimeters, a longitudinal section through a portion of the apparatus, an end view of the calorimeter, and a view of the same as seen from above.

The calorimeters are made of sheet brass No. 29, and are so shaped that when clamped together they may completely and closely include a portion of the pipe covering. A tube serves for the introduction of water, and the subsequent insertion of the thermometer, which is retained in place by a perforated cork. Another pipe in the bottom serves for drawing off the water by removing the cork. A glass tube, attached by a caoutchouc connector to a small brass tube in the end, shows the height of the water. The top piece, to the inner sides of which are soldered slotted brass plates, allows a wooden paddle to be swung back and forth on a brass pin, to equalize the temperature of the water. The perforated brass ears and the binding rods, with the thumb nuts, furnish the means of clamping the two halves over the pipe covering. Thick wooden washers give a chance to turn the thumb nuts past the edge of the slanting bottom.

A different mode of clamping was described by the author and illustrated in perspective and sectional views. In this, pine wood braces, held together by bolts, are distinct from the calorimeters. This mode of clamping was actually used in most of the experiments, but the wooden braces were not so easy to manage, and they were much in the way of the wrapping; for in use the whole apparatus was covered with cotton batting put on thick and held on by cotton twine wound around in various directions. Cotton wool makes a good and cheap covering, but it takes much time to apply it. Latterly, it seemed best to try other wrappers, and for the sake of greater compactness a modification of the apparatus was constructed, in which long sheaths receive the wooden rods, which are held by pins at one end and wooden wedges at the other. A calorimeter of this form was surrounded by a box of thin wood made much larger, so as to leave a space about 1½ inches thick all around the brass boxes—two pipes and the top piece, as well as the gauge, projecting outside the wooden box. The space was filled with nearly two pounds of live geese feathers. The feathers make an excellent non-conductor, but they are rather expensive, and by no means easy to handle.

Then a modified form of clamping arrangement was tried, and a cover was made of three thicknesses of very soft woolen blanket sewed on; this is rather costly, but it is, perhaps, the best wrapper to use. A wrapper of hair-felt was tried twice, but it was too tender to be used many times, and it did not admit of sewing on, but had to be held on with twine wound around.]

In making trials, the calorimeters are filled up with water 10° or 12° C. colder than the air of the room, the thermometers are inserted and the water is well agitated with the paddles. The temperature of the water, the steam pipe, and the air of the room, and the time are noted. Observations are made every half hour, or oftener, till the water stands 10° or 12° higher than the surrounding air. The water is then drawn off and weighed. The experiment is repeated times enough to give a fair average.

Of course, all the heat transmitted by the length of pipe covering enclosed by the apparatus is taken up by the water, and could be exactly determined were there no radiation from the calorimeter itself. But wrap as we may, there will still be a loss when the surrounding air is colder than the water. To neutralize the error from this source we should use only that part of the experiment which lies between two observations, in one of which the water is about as many degrees colder than the air as it is hotter in the other; thus, the absorption of heat from without in the first part of the time is balanced by the radiation from within in the latter part.

The calorimeter itself takes up heat as well as the contained water, and we must, therefore, add to the weight of the water as much as corresponds to the weight of brass and immediate surroundings, the specific heat being taken into account. For every calorimeter this is a constant quantity which may be determined practically by mounting the apparatus on an unheated pipe, wrapping it as usual. Cold water is run in and allowed to stand some time, the temperature being noted. Then the water is as quickly as possible run out and replaced by warm water of known temperature. After a thorough agitation the temperature is observed, and the warm water is drawn off and weighed.

Let t = the temperature of the cold calorimeter.

t' = the temperature of the warm water at first.

T = the temperature of the warm water after it is run in, and
a = the quantity of warm water drawn out and weighed.

If x = heat units taken up by the calorimeter, reckoned either in grams of water heated 1° C. or in pounds of water heated 1° F.; then

$$\mathrm{T} = \frac{a\,t' + t\,x}{a + x};\ \text{hence}\ x = \frac{a\,(t' - T)}{T - t}$$

In an actual trial, the water equivalent of the calorimeters A I, A II was found to be 194 grams for each.

In an experiment with covering No. 34 of the table hereto appended:

At 9 h. 15 m., A I stood at 12·63° C., and A II at 12·64°.*

At 3 h. 25 m., A I stood at 42·73°, and A II at 42·18°

Mean temperature of the air, 27·7° C.

Interval 370 minutes.

From A I were drawn off 3,260 grams of water; from A II 3,320 grams.

Calculating from these data:

$$(42{\cdot}73 - 12{\cdot}63)\ (3{,}260 + 194) \times \frac{60}{370} = 16{\cdot}859^\circ.$$

$$(42{\cdot}18 - 12{\cdot}64)\ (3{,}320 + 194) \times \frac{60}{370} = 16{\cdot}833^\circ.$$

The average of these and trials made on two other days, was one kilogram of water heated 16·671° C. per hour in each calorimeter. But the two brass boxes include 14 inches in length of the covering.

Hence $\frac{12}{14} \times 2 \times 16{\cdot}671 = 28{\cdot}579$ kilogram-centigrade heat units, or one kilogram of water heated 28·579 C°. per hour by each linear foot of the covering. To reduce this to pound-Fahrenheit heat units, we multiply by $\frac{9}{5} \times 2{\cdot}205$, which gives 113·43° per foot per hour.

Thus we have an absolute measure of all the heat which is transmitted by the covering. But it may, with some reason, be objected that the rapidity of transmission, and therefore the amount of heat passing off from a constant source in a given time, is influenced by the temperature and nature of surrounding bodies; and hence that the communication of heat to a fixed quantity of water is not necessarily the same as that actually given off to air in free circulation. Farther experiments are needed to determine exactly how the heat imparted to the water calorimeters compares with that given out to air by the freely exposed covering. We should naturally expect that as water has a higher specific heat than air it would induce a more rapid cooling, and that therefore the water calorimeter would give higher results than the condensation method. But we have a limited quantity of water allowed to get pretty warm as compared with an unlimited supply of cold air. In fact the coverings No. 24 and No. 25 of the appended table were intended to be alike, and were very nearly so. As the temperature of the steam averaged 150° C., its latent heat was 500° C. Now the quantity of water condensed per foot per hour in No. 25 was 46·5 grams. And $46{\cdot}5 \times 500 \times \frac{1}{1000} = 23{\cdot}250$ kilogram-centigrade heat units, while the calorimeter trial of No. 24 gave 22·807°. The difference is not large, and this tends to show that air-cooling and calorimeter-cooling are not very unlike.

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* Though throughout this report many temperatures are expressed in degrees with two decimal places, it should be understood that these are not actual readings, but in most cases the observed numbers have been corrected according to the calibration table of each thermometer; and in calibrating, it was thought as well to carry out the calculations to hundredths of a degree.

Any uncertainty as to whether water calorimeters show the actual loss of heat by pipe coverings does not affect their comparative indications respecting different coverings. A more important matter, perhaps, is the not unfrequent impossibility of exact fitting. Coverings that are plastered on are never of uniform thickness, nor are they exactly cylindrical. In such cases the contact of the calorimeters will be more or less imperfect, and radiation through confined air will be partly substituted for direct conduction. On the other hand, yielding coats, like hair felt, are somewhat compressed by clamping on the brass boxes, and yet more by the weight of the filled apparatus; and the more closely fibrous matter is compressed, the greater its transmitting power. So the results of the trials are likely to be somewhat too favorable to the hard and inelastic coverings.

In carrying out the examination of pipe coverings, it seemed best to get samples such that each one could be used for the three methods in succession. Accordingly, circulars were sent out requesting manufacturers and others interested in the subject to furnish whatever specimens they wished to have submitted to competitive trial. The directions called for pieces of ordinary two-inch steam pipe two feet long, cut with a right-hand thread at each end, and then covered, in the usual way, for a length of eighteen inches between the threaded ends. In response to this invitation, thirty-one samples were sent in by various makers, and eight kinds were brought and applied directly to our hot steam pipe in place. In only one or two instances have prices been given.

The room available for the experiments is an iron turning shop, through the upper part of which runs thirty-six feet of two-inch pipe, conveying to an engine steam of sixty pounds pressure. The engine is run in term time, from 8.45 A. M. to 12 M., and from 1.30 to 4.30 P. M. During the noon hour the pipe is full of hot but not moving steam. Before entering the room, the pipe runs about 110 feet from the boiler. Two lengths of the pipe in the room were taken out and replaced by as many as possible of the two-foot sample pipes coupled together. Near the middle of a set was inserted a T with a three-quarter inch side connection turned upwards. Into this was screwed a bushing furnished with a long thimble reaching nearly to the bottom of the T inside. [A longitudinal section of this disposition was exhibited showing the T; the plug; the thimble, made of a piece of three-eighths inch gas pipe capped and filed thin. A thermometer suspended in the thimble by means of the perforated cork, gives the temperature of the passing steam.]

Calorimeter and air chamber trials were made with each covering two, three, or sometimes four successive days. When one set was gone through with, another set was mounted in their place. But several of the samples had been so covered as to leave too little space for a good grip of the pipe wrench, and therefore could not be dismounted in fit condition for connecting again as side branches. Moreover, the number of specimens sent in was unexpectedly large, some makers furnishing many pieces differing more in size than in kind. Hence it was necessary to be content with setting up again for the condensation trials only such uninjured pieces as might represent the different types of coverings.

When the experiments with each piece were finished, the cover, while still at its maximum of dryness, was stripped off, dissected, and weighed; for, of course, the non-conducting power is not the only thing to be considered. We must take into account the cost, weight, bulk, necessary thickness, durability, ease of application, ease of removal, repair and renewal, simplicity, appearance, freedom from smell, temptation to insects or mice, hardness, resistance to moisture, combustibility, liability to crack, and the possible chemical effect on the pipe.

Pipe coverings may be divided into four general classes:

1. Those consisting essentially of light fibrous matter, as hair, slag wool, or paper, applied immediately to the pipe.

2. Those composed of a paste or mortar, which is plastered directly on the pipe, in one or several coats.

3. Those having an air space next the pipe.

4. Complex combinations of different layers.

It will be seen that of all the coverings tried, as shown by the annexed table, the most efficient was simple hair felt with a cheap cover of burlap. It appears also that of the whole number, seventeen owe their efficacy to hair.

Slag wool came third in rank; but it should be noticed that this was a most remarkable covering. The slag wool was two inches thick and was surrounded by wooden slats one inch thick, these being covered with three thicknesses of cloth. So the whole was enormously and absurdly bulky. On the other hand, this wool was not of commendable quality, for it parted with 38 per cent. of heavy globules when it was thrown on a sieve, and this superfluous portion had increased the weight without doing any good. A more feasible covering was tried in Nos. 24 and 25, with the very same fibre after sifting out the shotted slag. This one inch coating showed a fair result, though of course, by long heating and sifting and handling, the fibre had become much broken, and could not therefore be as efficient as new wool. It was desirable to try new slag wool, of the best quality, but the dealers in the article were unwilling to sell a small quantity. No doubt the best kind would give a more favorable result than that shown in No. 24, and would prove really more economically than the cheap sort. I suppose this latter kind is the same substance that is known in England under the misleading name of "silicated cotton."

Spongy paper, as in No. 16, proves to be a tolerable good non-conductor. In a condensation experiment not given in the table, Reed's covering gave a net result of forty-six grams per foot per hour, which almost coincides with that of slag wool in No. 25.

Straw covered with cotton cloth, as in No. 28, does not show an encouraging degree of excellence.

The otherwise useless rice chaff of No. 18, moistened with water-glass to make it less inflammable and somewhat coherent, proved much more efficient than straw rope.

It should be remembered, fibrous or porous matter acts mainly by virtue of entrapped air, and hence the looser it is the better. Thus everybody knows that hard-spun woolen stuffs do not make warm clothing. Asbestos is commonly supposed to have wonderful virtue in resisting heat, but there is really no magic power in the mineral fibre. It is a non-conductor only when it is in a light, downy condition and full of air. The figures given in No. 50 show that hard-pressed asbestos paper conducts heat very readily. And it was observed that in those cases in which asbestos paper is put between the pipe and hair felt, the asbestos fails to prevent the scorching of the hair. Incombustibility should not be confounded with non-conducting power.

As to the second class, the plastered coverings, none seems to be worth much except the diatomaceous earth or "Fossil Meal," of Nos. 21, 26 and 27. Of only one or two of them was the exact composition known, but there is not one of such excellence that the secret of its composition is worth keeping. Most of the pastes have an admixture of hair, vegetable fibre, or asbestos, to make them tougher and keep them from cracking. The more organic fibrous stuff can be worked in the better, for it makes the covering lighter and looser and hence less capable of transmitting heat. When such fibres are surrounded by clay, plaster, or other mineral matter, it makes little difference whether they are of themselves combustible or not; they cannot char or burn unless used in connection with steam of extremely high pressure, or super-heated steam. So here again, as compared with animal or vegetable fibres, asbestos, which is really a heavy mineral, has more plausibility than positive virtue. Most of the makers of plastered coverings appear to have been experimenting with materials that are too dense.

To the third class, those with greater or less air space, belong Nos. 9, 12, 19, 20, 22, 23, 34 and 37.

With regard to the efficiency of coverings with an air space, the experiments so far are not decisive, because in no two trials was it certain that the material was otherwise of precisely the same quality and thickness. In Nos. 34 and 36, which were apparently the same, with the exception of an additional wire gauze support in No. 34, the air space showed but a very slight advantage. The comparison of Nos. 16 and 19 is even unfavorable to the narrow air space.

But when there is no visible covering at all, as in Nos. 47, 48 and 51, it makes a wonderful difference whether the calorimeter comes in direct contact with the pipe, or a thin stratum of air intervenes. It seems, too, that a quarter of an inch of air is as good as an inch. This calls to mind the well-known fact that one may safely stay a few moments in the air of a room heated to a point much above the boiling-point of water, as in the old "hot room" of calico print works; but if the skin touches a metallic body or a liquid of the same temperature, burning or scalding ensues.

So it was also observed that when hair or paper remained for a considerable length of time in contact with the hot steam pipe the organic matter became browned or scorched, while the hair felt in No. 9 remained, to all appearances, entirely unchanged, except at the ends where it was gathered in and touched the pipe. It might be thought that the bright tin plate case, as such, had something to do with preventing the scorching; for, from the tradition of Leslie's old experiments on heat, a surface of bright tin is reputed to be a poor radiant and recipient. But when the mere tin case of No. 9 and the straw-board case of No. 20 were put on the pipe, side by side, the tin box soon became hotter than the hand could bear, while the straw-board could be handled.

An air space, then may prove very useful in obviating one of the great objections to coverings of organic fibrous matter, though it is not specially beneficial in other respects. Woolly asbestos or asbestos paper, which the makers of some of the specimens appear to have relied on for this purpose, does not accomplish the object, for in all those samples in which a wrapping of asbestos came between hair and the pipe, the hair, after the trials, was found to be discolored by the heat. And then again, experiments Nos. 47 and 50 show that a wrapping of asbestos paper does not insulate so well as the same thickness of mere air. The popular confidence in asbestos partakes of the character of a superstition.

Coverings of the fourth class, those made up of many layers of different kinds, have not proved better or more efficient than the simpler ones; and we may justly set down much of the ingenuity shown in devising coverings of this class as fruitless. Of course, complexity enhances the cost, and there should be some corresponding advantage.

But of the actual prices charged, I have received statements in only one or two instances. It is evident, however, from the labor necessarily required to produce some of the specimens, that cheapness has not been kept sufficiently in mind. The question as to whether a covering shall be used or not is one mainly of dollars and cents, and the inquirer must be satisfied that the saving of heat will soon make up for the outlay.

From No. 51, it appears that a naked two-inch pipe, carrying sixty pound steam, may condense 181 grams per foot per hour, and No. 25

shows that a cheap covering may reduce this to 46·5 grams, making a saving of 134·5 grams per hour, or 1·345 kilos. = 2·96 lbs. of steam in a day of ten hours. So the covering of one hundred feet of pipe would save in a year of 300 working days, coal enough to convert 88,800 lbs. of water into steam. If we consider one pound of coal as capable of making 8·88 lbs. of steam, we shall have a saving of five tons of coal per year for one hundred feet of the covering. So, where coal is worth $5 per ton, it would certainly be worth the while to use a covering costing not more than twelve cents per foot, but we might wish to think twice before taking one worth twenty-five cents per foot.

In some cases it may be worth the while to add a little to the expense for the sake of securing a good appearance and having a covering that can be easily kept clean. An encasement of cotton duck or canvas looks well, whether the cloth is drawn together by the edges and stitched, or is torn into narrow strips and wound around spirally. Except the costliness of this closely woven stuff, the only objection to such a jacket or bandage is its combustibility, and this ought to be obviated by painting the canvas with water-glass. Some of the plastered coverings sent in have a hard, smooth exterior finishing coat, which gives a pretty appearance, but adds too much to the already excessive weight.

The weight and bulk of a covering are of some consequence, for if we add to the pipe three or four times its weight or size of other matter, we make it troublesome to support. A coating over five inches in diameter for a two-inch pipe seems absurdly disproportionate; and as the pipe itself weighs fifty-six ounces per foot, an additional weight of sixty ounces or more is altogether beyond reason. The weights given in the table show that some makers have sinned grievously in this matter. In the large and heavy specimens tried, excepting No. 3, there appears to be a lack of efficiency, and there is little else to commend them.

Of course, for every kind of covering there is an optimum of thickness beyond which the cost and bulk of any addition is not compensated by any further gain in efficiency, and this best size can be approximately determined only by a series of careful experiments with each particular substance or composition. As most of my trials have been of ready-made coverings furnished by others, there are few data for reasoning about the matter of thickness. In comparing Nos. 1

and 2, we see that an increase of hair beyond an inch of thickness, or thirteen ounces of weight per foot does very little good.

Nos. 27 and 35 were made with the same fossil meal paste, and put on by the same person; and here we see that a much less thickness than one inch of fossil meal is insufficient.

Though Nos. 3 and 24 are not strictly comparable, the two taken together go to show that when poor slag wool is used it will pay to have it considerably more than an inch thick.

As to ease of application, repair or renewal, Reed's covering, Nos. 16 and 19, and the Chalmer Spence Co.'s complex tubes, Nos. 6, 10, 12 and 17 stand foremost. These are molded into form and partially bisected lengthwise—Reed's so as to leave merely a thickness of paper for a hinge, and the Chalmer Spence through one side of the hollow cylinder—so the tube has only to be opened or sprung apart somewhat, clasped over the pipe, and fastened together at the meeting edges with double pointed tacks. The covering can be taken off at any time by taking out the tacks and prying the joints apart. Next to these comes hair felt which can be cut of suitable width, clasped around the pipe, and held on by winding string or fine wire around spirally. It may be left so, or cloth can be sewed on around it.

Straw rope can be wound around spirally at a pretty rapid rate, but in time it becomes so brittle that it is worthless when unwound again.

In No. 37, the tin plate cylinders are made in halves which lock together and are more easily put on than taken off. The inner case is held off from the steam pipe, to make an air space, by means of short corrugated tin plate rings.

The tin plate case of No. 9 is made in one foot lengths, with two opposite longitudinal ribs projecting inwards. Each length is made in halves and the ribs are formed by turning in the edges so that they come double when the two halves are put together and fastened with solder. The cylinders are so joined end to end that their ribs lie in planes at right angles to each other. Both this covering and No. 37 are lacking in simplicity and ease of adjustment.

The air space of No. 19 is made in a ready way by winding around the pipe narrow strips of asbestos paper, some distance apart, before the covering is clamped on. In No. 12 the complex cylinder of hair and pasteboard is held off from the pipe by short, thick paper cylinders.

In No. 20, the air space was made in a cheap and easy way with rings of plaster of Paris placed a foot apart, and a cylinder of straw board sprung on over them. This straw board had been shaped by rolling it in the machine with which tinkers form stove pipe, and was made large enough to have one edge lap over the other a little. The plaster rings were made in halves, with a groove around the outside, to receive the string with which they were tied together on the pipe. Such rings can be cast with little trouble, and they should be well dried before using. They could be made of porous terra cotta at trifling cost, and it would be better to fasten them on with small wire. The half rings in No. 22 were cut out of thin pine boards with a scroll saw, and the straw board was tacked to them; but pine rings shrink and become scorched, while those of plaster or burned clay are hard, incombustible, and poor conductors of heat. The case of No. 24 was made in the same way, but with an incomplete cylinder of straw board, so that there was left, along the whole length of the upper side, a narrow aperture through which the slag wool was crowded in. The long aperture was closed over with a somewhat wider strip of straw board, the whole being finally held together by winding twine around.

The rice chaff of No. 18, the sphagnum of No. 22, and the charcoal of No. 29 were put on with the help of a wire cage specially contrived for the purpose.

It requires some practice to put on paste coverings with a trowel, and it is by no means easy to get them uniform and round. With the exception of the fossil meal, the plastered coverings are worthless when they are taken off.

I have observed no chemical action by any of the coverings except such as contain plaster of Paris, which, while wet, rusts iron rapidly. The corrosion of pipe, which is said to have occurred sometimes with slag wool that had become damp, must have been caused by the sulphate of lime formed by the oxidation of a trace of sulphide of calcium in the slag.

Respecting durability, little can be learned by trials lasting only a few weeks. But it is well known that animal and vegetable substances undergo a change by long-continued heating, and this sometimes becomes obvious even after a few days' exposure. Wool, hair, cotton and paper in contact with a pipe at 150°C., soon turn brown and have their elasticity much impaired. To be sure, it is only a moderate thickness that becomes so affected, and samples of old coverings that have been sent me show that it takes years to scorch any considerable portion of the whole depth.

Straw suffers farther out than the poorer conductors. Specimen No. 39, which was said to have been in use nine years, was still bright and straw-like outside, but the steam pressure had been under fifteen pounds. The straw alone in this sample weighed 4·2 ounces per foot, while the new straw of No. 28 weighed 10·6 ounces. If No. 28 really represents the original dimensions and character of No. 39, as it was intended to, the impairment of efficiency by the shrinkage bears a strikingly small proportion to the loss of weight.

The change of organic matters by a steam heat is too slow to produce any sensible odor, but if by any chance hair felt gets wet while on the pipe, it gives out an unpleasant smell for a long time. I have known instances in which this proved so great an annoyance that the covering had to be stripped off; and the possibility of such an occurrence is no slight objection to the use of hair in immediate contact with the hot pipe. The intervention of an air space offers a possible prevention of this trouble as well as of the crisping of the hair.

As to the chances for spontaneous combustion of any covering consisting of vegetable fibre, it is difficult to pronounce with certainty. There is a report in circulation that a certain paper covering has taken fire of itself; but I believe this is rather a matter of interested surmise than of positive proof. I put two pieces of the indicted covering on a pipe near the boiler, where the temperature was very high outside and at least 150°C. within the pipe—one of the pieces as it came from the maker, the other charged with cotton-seed oil (this oil readily induces the combustion of cotton waste), and yet both the paper tubes remained so exposed to heat for six months without showing the slightest inclination to take fire.

Of course, coverings made of organic substances become excessively dry and tinder-like when they are constantly exposed for a long time to a steam heat, and then they very readily catch fire when a spark or a flame touches them. Therefore, though there is little danger of fire from within, it is well to guard against fire from without. The impregnation of cloth wrappings with borax, tungstate of soda, or water-glass is calculated to lessen very much the danger from fire.

In connection with the testing of what were offered for fire-proof window shutters some years ago, I was led to believe that one of the best and cheapest non-conductors could be made of water-glass and wood charcoal, since by charring, all gas-forming material is eliminated from the wood, and carbon does not oxidize rapidly when covered with the varnish-like and fusible silicate. It was this mixture that I tried in No. 29; but as there was no light pine charcoal at hand I was obliged, by want of time for making some, to take a rather too dense substitute. Still the result is encouraging, and I hope to follow up the matter farther, for this concreted uninflammable coal is capable of many useful applications.

The rice chaff in No. 18 was also mixed with enough water-glass to render it somewhat coherent when dry, and as the chaff is itself rather silicious we thus get a covering so charged with mineral matter as to be hard to set on fire, and at the same time quite light and efficient as a non-conductor. Doubtless, chopped straw might be used in the same way. But sawdust soaks up so much water-glass as to make a paste that dries too dense.

Coverings that contain flour or meal are liable to be troubled somewhat by mice. Even silicated rice chaff is not altogether proof against them. These animals also gnawed the interior of specimen No. 12.

When it is desirable to have a covering water-proof outside, this can be effected best by putting on a wrapper of sized cloth and applying to it one or two coats of oil paint. Of course, this should be done only after the covering has become perfectly dry. But trouble is sometimes caused from within, by leaking joints, and in such a case a water-proof coat only occasions a spreading of concealed mischief inside. On the other hand, a very porous coating allows the vaporized water to escape, and, if the leak is slight, no harm is done. It is well to use a pretty loose material for covering the joints, to separate those parts from the rest by impervious diaphragms of tin plate or plaster, and to make them so that they can be easily removed without disturbing the other portions.

The following table of specimens tried, Table I, is arranged in the order of their transmitting power as shown by the calorimetric method. The first column gives the source from which each of the samples was obtained, together with a concise description of the make up, beginning with the coating next the pipe. Those marked "J. M. O." were home productions.

The maximum diameter is given in the second column, few being quite cylindrical.

The weight in the third column includes the average of the whole of the covering, but in many cases the essential part constitutes only a moderate portion of the whole weight. Fuller details of the structure are given in the second table.

The fourth column gives the highest temperature observed in the air chambers durings the trials. In one or two instances the covering was so irregular that the air chambers could not be made to fit closely enough for a fair trial, and so no figure is given.

The numbers in the fifth column show the condensation by each foot of the covered pipe in one hour. "Gross" signifies that the condensation by the fittings and extra pipe is not allowed for, and the figures given are, therefore, really from one-fourth to one-third too high. The method given above for eliminating this error was not invented till most of the trials had been made. In the trials made latterly the word "net" shows that the proper deduction has been made. It takes many days to get the data for the requisite correction, and it is hardly worth the while to spend the time for this, with many samples, till further careful experiments shall show whether the matter of mist really vitiates the results of the condensation method as much as we may suppose it can.

The sixth column shows how many heat units are actually transmitted in an hour by one foot in length of the pipe covering—that is, how many degrees centigrade one kilogram of water may be heated by it, or how many kilograms of water may be raised 1° C.

In the last column the same loss of heat is expressed in degrees Fahrenheit which one pound avoirdupois of water may be heated.

As all the samples beyond No. 30 allow more than twice as much heat to pass through as is transmitted by No. 1, it would seem that in No. 31 and all after it, there is much room for improvement.

The average of the 46 coverings—No. 50 being left out—is 24·623 kilogram-centigrade heat units transmitted.

The average weight is 49 ounces, or a little over three pounds per foot.

TABLE I.

		Diameter of Covering.	Weight per foot in oz. Av.	Maxim'm heat in air chambers.	Condensed 1 ft., 1 hour, in grams.	Kilo-cent'g Heat units 1 ft., 1 hour.	Pound-Fahr. Heat units, 1 ft., 1 hour.
		In.		Deg. C.		Deg.	Deg.
No. 1.	From LOWELL FELTING MILL—I. Hair felt, with single cover of burlap	5⅜	21·4	53·98	40·67 gross.	12·842	50·966
No. 2.	From LOWELL FELTING MILL—II. Hair felt, with single cover of burlap	4½	13·2	58·0	....	12·999	51·590
No. 3.	CHALK & LAWTON, Pawtucket, R. I.—II. Slag wool, wooden cage, burlap, cotton cloth, double	8	117·8	39·5	43·00 gross.	14·465	57·408
No. 4.	H. W. JOHNS' Non-Cond. Covering—II. Asbestos fibre, asbestos paper, hair felt, asbestos paper, hair felt, asbestos paper, canvas	5⅜	29·3	47·88	....	14·498	57·539
No. 5.	GREENWOODS CO., New Hartford, Conn. Asbestos paper, hair felt, canvas	4½	17·3	61·8	....	15·074	59·705
No. 6.	CHALMER SPENCE CO., New York—II. Asbestos paper, hair and pasteboard coiled together	4⅝	30·1	55·65	....	15·713	62·361
No. 7.	ASBESTOS PACKING CO.—III. Asbestos paper, double, hair felt, paper, canvas	4½	19·9	51·61	....	15·761	62·551
No. 8.	ASBESTOS PACKING CO.—II. Asbestos paper, hair felt, paper, canvas	5	18·1	53·16	41·00 gross.	16·078	63·809
No. 9.	CHALMER SPENCE CO.—V. Air space, tin plate case, hair felt, canvas	4¾	20·8	57·0	....	17·122	67·952
No. 10.	CHALMER SPENCE CO.—I. Asbestos paper, hair and pasteboard coiled together	4⅜	21·7	62·0	51·00 gross.	17·551	69·255
No. 11.	H. W. JOHNS' Non-Cond Covering—VI. Asbestos paper, hair felt, paper, canvas	4	17·2	61·9	....	17·801	70·647
No. 12.	CHALMER SPENCE CO.—IV. Air space, asbestos board, hair felt, asbestos paper, hair felt, pasteboard	6½	58·1	59·7	....	18·588	73·717
No. 13.	H. W. JOHNS' Non-Cond. Covering—I. Asbestos paper, asbestos paste, hair felt, asbestos board, hair felt, asbestos board, canvas	7¼	105·3	48·22	....	19·291	76·385
No. 14.	J. H. GRAHAM & SON, Boston—III. Clay, paper, hair felt, laths, plaster	5	52·9	....	....	19·423	77·085
No. 15.	J. H. GRAHAM & SON—V. Asbestos paper, hair felt, paper, canvas	4½	16·1	65·0	....	19·632	77·913
No. 16.	REED'S Covering—I. Paper cylinder, joint covered with paper	4⅜	30·5	61·0	....	19·670	78·064
No. 17.	CHALMER SPENCE CO.—III. Asbestos paper, hair and asbestos paper coiled together	4⅝	30·3	53·5	....	20·129	79·886
No. 18.	J. M. O. Silicated rice chaff, cotton cloth cover	4¾	22·7	60·0	....	20·203	80·181
No. 19.	REED'S Covering—II. Air space, asbestos paper, paper cylinder	4¾	29·[illegible]	....	....	20·439	81·117

TABLE I—*Continued.*

	Diameter of Covering	Weight per foot in oz. Av.	Maxim'm heat in air chambers.	Condensed 1 ft., 1 hour, in grams.	Kilo-cent'g Heat units 1 ft., 1 hour.	Pound-Fahr. Heat Units, 1 ft., 1 hour.
	In.		Deg. C.		Deg.	Deg.
No. 20. J. M. O. Air space, straw-board, hair felt, no cover	4¾	12·0			20·693	82·124
No. 21. S. C. NIGHTINGALE & CHILDS—IV. Fossil meal and hair plastered on	4¾	60·7		58·00 gross.	21·151	83·940
No. 22. J. M. O. Air space, straw-board, peat moss, cotton cloth	4¾	10·6			21·631	85·818
No. 23. J. H. GRAHAM & SON—I. Air space, hair felt, laths, plaster	5⅜	63·1	51·4		21·820	86·596
No. 24. J. M. O. Slag wool, straw-board	4¼	21·1			22·807	90·510
No. 25. J. M. O. Slag wool, straw-board	4⅜	24·8		46·50 net.		
No. 26. S. C. NIGHTINGALE & CHILDS—I. Fossil meal and hair plastered on	4¼	31·9	61·5		22·942	91·050
No. 27. S. C. NIGHTINGALE & CHILDS—II. Fossil meal and hair plastered on	4⅛	26·9			23·462	93·113
No. 28. W. E. PARKER, Pacific Mills—I. Rye straw rope wound around, cotton cloth 4 ply	4½	20·2	64·8	55·00 gross.	24·424	96·933
No. 29. J. M. O. Silicated hard wood, charcoal, cotton cloth cover	5	41·9		47·00 gross.	24·650	97·830
No. 30. J. M. O. Carbon, plaster of Paris, flour and hair plastered on	4½	33·0			26·909	106·800
No. 31. ASBESTOS PACKING CO.—IV. Asbestos paste, clay and flax, paper pulp, mortar	5½	100·1	63·0		27·411	108·78
No. 32. J. M. O. Dry rice chaff, straw board	3¾	8·4			27·607	109·56
No. 33. J. H. GRAHAM & SON—IV. Asbestos and clay, laths, paper, mortar	5	58·0	66·0		28·159	111·75
No. 34. CHALMER SPENCE CO., "Patent Air Space." Half-inch air space, wire netting, asbestos paste	5	41·0	72·8	74·00 gross.	28·579	113·43
No. 35. S. C. NIGHTINGALE & CHILDS—III. Fossil meal and hair	3¼	17·1			28·882	114·62
No. 36. CHALMER SPENCE CO., "Solid Covering." Asbestos paste	4½	31·4	74·2	61·00 gross.	29·599	117·47
No. 37. CHALK & LAWTON—II. Air space, tinplate case, asbestos paper, tinplate case	4	29·0	52·14		29·660	117·71
No. 38. EUREKA COVERING CO., Fitchburg, Mass. Meal, clay and hair, meal, clay, sawdust, flax fibre	5¼	81·9	70·0	79·00 gross.	30·171	119·74
No. 39. W. E. PARKER, Pacific Mills—II. Rye straw rope, cotton cloth 6 ply (after nine years' use)	4¼	9·8	70·8		30·286	120·20

TABLE I—*Continued.*

		Diameter of Covering	Weight per foot in oz. Av.	Maxim'm heat in air chambers.	Condensed 1 ft., 1 hour, in grams.	Kilo-cent'g Heat units 1 ft., 1 hour.	Pound-Fahr. Heat Units, 1 ft., 1 hour.
		In.		Deg. C.		Deg.	Deg.
No. 40.	ASBESTOS PACKING CO.—I. Asbestos paper, plaster and flax fibre	5⅞	111·5	73·8	....	31·267	124.09
No. 41.	J. H. GRAHAM & SON—II. Plaster paste	5	67·5	79·8	....	33·477	132·86
No. 42.	SAMUEL TAYLOR'S Non-Cond. Composition. Clay and short fibrous matter	5¼	91·1	77·3	....	36·782	145·98
No. 43.	H. W. JOHNS' Non-Cond. Covering—IV. Asbestos paper, asbestos paste	6¼	201·8	69·2	....	37·951	150·61
No. 44.	J. M. O. Anthracite ashes, plaster of Paris, flour, hair	4¾	79·2	....	....	39·159	155·41
No. 45.	H. W. JOHNS' Non-Cond. Covering—V. Asbestos paper, asbestos paste	6½	171·2	70·0	....	41·079	163·03
No. 46.	H. W. JOHNS' Non-Cond. Covering—III. Asbestos paper, asbestos paste	5¼	99·8	77·8	87·00 gross.	43·097	171·04
No. 47.	J. M. O. Mere air space	2 5/16	....	....	....	49·211	195·42
No. 48.	J. M. O. Mere air space	4¾	....	....	....	50·405	200·04
No. 49.	FALL RIVER STEAM PIPE COVERING CO. Clay and refuse of vegetable fibre	4¼	65·2	91·8	....	51·727	205·29
No. 50.	J. M. O. Asbestos paper wound round four times	2⅞	....	....	....	56·371	223·72
No. 51.	J. M. O. Naked pipe	2 11/32	....	....	181·00 net.	391·830	1555·10

TABLE II.

No. 1. Hair felt, 826 grams; Burlap and twine, 85 grams. Length 18 inches.

No. 2. Hair felt, 493 grams; burlap, 50 grams; twine, 17 grams. Length, 18 inches.

No. 3. Slag wool, 2 inches thick, 3860 grams; wooden slats, ¾ inch thick, and nails, 1815 grams; wooden rings at ends, 1⅝ inches thick, 540 grams; tinplate rings between Wooden rings and pipe, 51 grams; burlap, 127 grams; cotton cloth two thicknesses, and paint, 270 grams; tacks, 13 grams. Length, 24 inches.

No. 4. Asbestos paper faced with loose asbestos fibre, 16½ × 25 inches, 205 grams; ¾ inch hair felt, 18 × 10½ inches, 282 grams; twine, 3 grams; asbestos paper, 17½ × 18 inches, 112 grams; ¾ inch hair felt, 17½ × 14 inches, 407 grams; twine, asbestos paper, 17½ × 16 inches, 133 grams; canvas, 19 × 18 inches, 80 grams. Length, 17½ inches.

No. 5. Asbestos paper, 119 grams; twine, 4 grams; hair felt, 458 grams; canvas, 94 grams. Length, 16½ inches.

No. 6. Hair and pasteboard, not easily separated. Whole weight, 1280 grams. Length, 18 inches.

No. 7. Asbestos paper doubled, 110 grams; hair felt, 486 grams; paper, 157 grams; canvas and string, 93 grams. Length, 18 inches.

No. 8. Asbestos paper, two thicknesses, 98 grams; hair felt, 1¼ inches thick, 16½ inches thick, 16½ × 12 inches, 456 grams; twine, 6 grams; paper, 17¾ × 31½ inches, 156 grams; canvas, 87 grams. Length, 17½ inches.

No. 9. Tinplate case and ribs, 580 grams; 1 inch hair felt, 494 grams; canvas and twine, 94 grams. Length, 23 inches.

No. 10. Hair and pasteboard cemented together. Whole weight, 910 grams. Length, 17¾ inches.

No. 11. Asbestos paper, three thicknesses, 172 grams; twine, 6 grams; 1 inch hair felt, 552 grams; twine, 23 grams; paper, 123 grams; canvas, 81 grams. Length, 23½ inches.

No. 12. End pieces of paper, 3 inches long, lined with asbestos paper, 575 grams; asbestos paper, hair felt and pasteboard cemented together, 1860 grams. Length, 17¾ inches.

No. 13. Asbestos paper, two thicknesses, 167 grams; asbestos paste, 1 inch thick, 2910 grams; ⅝ inch hair felt, 385 grams; twine, 5 grams; asbestos board, 220 grams; ⅝ inch hair felt, 505 grams; twine, 6 grams; asbestos board, 301 grams; canvas, 107 grams. Length, 18½ inches.

No. 14. Clay, 760 grams; paper, 115 grams, hair felt, 280 grams; laths, 430 grams; iron wire and plaster, 2270 grams. Length, 29 inches.

No. 15. Asbestos paper, several thicknesses, 299 grams; hair felt, 425 grams; twine, 2 grams; paper, 198 grams; canvas, 137 grams. Length, 28 inches.

No. 16. Alike throughout, 1280 grams. Length, 17¾ inches.

No. 17. Hair and asbestos cemented together, 1290 grams. Length, 18 inches.

No. 18. Silicated rice chaff, 1060 grams; wooden rings and cloth wrapper, 120 grams. Length, 22 inches.

No. 19. Asbestos paper rings, paper tube, whole weight, 1230. Length, 17¾ inches.

No. 20. Wooden rings and straw board, 249 grams; hair felt and twine, 443 grams. Length, 24½ inches.

No. 21. Fossil meal and hair, alike throughout, 2940 grams. Length, 20½ inches.

No. 22. Wooden rings, 87 grams; straw board, 192 grams; tacks, 5 grams; outer rings of paper, 1¼ inches wide, 113 grams; sphagnum, 174 grams; cloth, 40 grams. Length, 24½ inches.

No. 23. Two iron rings, 1 inch wide, and tacks, 440 grams; ¾ inch hair felt, 218 grams; laths, 351 grams; wire and plaster, 2350 grams. Length, 21½ inches.

No. 24. Gypsum rings, 256 grams; straw-board cover, 201 grams; slag wool filling, 940 grams. Length, 24½ inches.

No. 25. Plaster ends, 253 grams; straw-board, 175 grams; slag wool filling, 802 grams. Length, 21 inches.

No. 26. Hair and fossil meal, uniform throughout, 980 grams. Length, 13 inches.

No. 27. Fossil meal and hair, uniform throughout, 1270 grams. Length, 20 inches.

No. 28. Straw rope, 1 inch thick, 400 grams; cotton cloth, four thicknesses, 400 grams; iron rings at the ends, not included in the weight given in Table I. Length, 16 inches.

No. 29. Silicated charcoal, 1760 grams; wooden rings and cloth wrapper, 120 grams. Length, 19 inches.

No. 30. Paste of plaster, carbon, flour and hair, 1560 grams. Length, 20 inches.

No. 31. Asbestos paste, 820 grams; clay and fibre, 960 grams; paper pulp, 1560 grams; twine, 23 grams; mortar, 3260 grams. Length, 42 inches.

No. 32. Wooden rings, 74 grams; straw board, 166 grams; tacks, 5 grams; rice chaff filling, 240 grams. Length, 24½ inches.

No. 33. Asbestos and clay, 580 grams; wood and wire, 325 grams; paper, 332 grams; plastering, 2052 grams. Length, 24 inches.

No. 34. Wire netting and sheet iron props, 210 grams; asbestos paste, 1340 grams. Length, 16 inches.

No. 35. Fossil meal and hair, uniform throughout, 770 grams. Length, 19 inches.

No. 36. Asbestos paste, uniform throughout, 1300 grams. Length, 16 inches.

No. 37. Corrugated rings of tin plate, 97 grams; tin plate cylinder, 345 grains; asbestos paper, 204 grams; tin plate cylinder, 445 grams; tin plate ends, 30 grams. Length, 16¾ inches.

No. 38. Two kinds of paste not separated, 3290 grams. Length, 17 inches.

No, 39. Straw rope, 160 grams; six thicknesses cotton cloth, 212 grams; iron rings at ends not reckoned. Length, 16 inches.

No. 40. Asbestos paper, 179 grams; three coats plaster with fibre, 4430 grams. Length, 17½ inches.

No. 41. Paste, uniform throughout, 5740 grams. Length, 36 inches.

No. 42. Clay and fibre, uniform throughout, 3500 grams. Length, 15¾ inches.

No. 43. Asbestos paper and twine, 102 grams; asbestos paste, 8760 grams. Length, 18½ inches.

No. 44. Ashes, plaster, flour and hair, uniform throughout, 3740 grams. Length, 20 inches.

No. 45. Asbestos paper, 113 grams; asbestos paste, 7370 grams. Length, 18½ inches.

No. 46. Asbestos paper, asbestos paste together, 4320 grams. Length, 18½ inches.

No. 47. Clay and fibre, alike throughout, 2310 grams. Length, 15 inches.

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Air space, Nos. 9, 12, 19, 20, 22, 23, 34, 37, 47, 48.
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Samuel Taylor's non-conducting composition, No. 42.

PRESSURE ATTAINABLE BY THE USE OF THE "DROP PRESS."

By ROBERT H. THURSTON, Hoboken, N. J.

[Read before the American Society of Mechanical Engineers, November, 1883.]

The writer has recently taken occasion to determine the magnitude of the pressures attainable and not infrequently utilized in the use of the "drop press," now so extensively employed in the process of "drop forging" and in the manufacture of small parts of sewing machines, firearms and light machinery.

The opportunity was afforded to make this determination in the course of an investigation of the efficiency of drop presses lately made by the Mechanical Laboratory of the Stevens Institute of Technology. It was found that the most efficient presses experimented with had an "efficiency," as the term is technically used, of 90 per cent.—*i.e.*, the work done by the drop was 90 per cent. of that which was due to the weight falling through the measured height. The table given below is based upon the assumption that this efficiency can be reached, and exhibits the mean pressure attained when the piece attacked is crushed to the amount of $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$ inch respectively. The maximum pressures must exceed those given. The mean pressures are calculated by determining the amount of energy of the falling drop at the instant before stopping—*i.e.*, of the quantity of work done upon it by gravity and stored in it, and dividing that measure in foot-pounds by the distance through which the crushing of the "work" takes place. These figures are seen to be simply enormous, and the power of this form of press is evidently limited only by the rigidity of its parts and their strength.

The figures given for the pressures reached when the compression is $\frac{1}{16}$ inch can be obtained only when the anvil is so set and of such material that the yielding there occurring cannot absorb more than the allowed 10 per cent. of the total work of the falling mass. The same remark applies to the table generally, but the loss may always be expected to fall within the assumed figure for the smaller weights and lesser heights fallen through. If the machine is well built and the anvil and foundation are of ample size and rigidity for good work, it is not improbable that the higher figures can be readily obtained; provided also that proper precautions are taken in the setting of the press.

The *intensity* of pressure attainable is evidently determined by the area of the surface exposed to the action of the drop, and this in turn determines the distance through which crushing may occur. The figures given in the table are total pressures, and the meam intensity of pressure corresponding to these amounts is to be obtained by dividing the total pressure as shown in the table by the area of section of the crushed piece, or by the mean area opposed to the crushing action during the operation. The proper comparison is that of the energy of the falling weight with the "resilience," elastic or total, or both, of the mass on the anvil or in the dies.

PRESSURES OF THE DROP-PRESS.—(EFFICIENCY 90 PER CENT).

Fall of drop in feet and inches.	Compression in inches.	Weights of Drop								
		Pounds. 50.	Pounds. 100.	Pounds. 200.	Pounds. 400.	Pounds. 600.	Pounds. 800.	Pounds. 1,000.	Pounds. 1,500.	Pounds. 2,000.
0′3″	1-16″	2,160	4,320	8,640	17,281	25,921	34,562	43,202	64,803	86,405
	⅛″	1,080	2,160	4,320	8,640	12,960	17,281	21,601	32,401	43,202
	¼″	540	1,080	2,160	4,320	6,480	8,640	10,800	16,200	21,601
0′6″	1-16″	4,320	8,640	17,281	34,562	51,843	69,124	86,505	129,607	172,811
	⅛″	2,160	4,320	8,640	17,281	25,921	34,562	43,202	64,803	86,405
	¼″	1,080	2,160	4,320	8,640	12,960	17,281	21,601	32,402	43,202
0′9″	1-16″	6,480	12,960	25,921	51,843	77,764	103,686	129,608	174,412	259,216
	⅛″	3,240	6,480	12,960	25,921	38,882	51,843	64,804	87,206	129,608
	¼″	1,620	3,240	6,480	12,960	19,441	25,921	32,402	43,603	64,804
1′0″	1-16″	8,640	17,281	34,562	69,124	103,687	138,249	172,811	259,216	345,622
	⅛″	4,320	8,640	17,281	34,562	51,843	69,124	86,405	129,608	172,811
	¼″	2,160	4,320	8,640	17,281	25,922	34,562	43,202	64,804	86,405
1′,6″	1-16″	12,960	25,921	51,843	103,686	155,529	207,373	259,216	388,824	518,432
	⅛″	6,480	12,960	25,921	51,843	77,764	103,686	129,608	194,412	259,216
	¼″	3,240	6,480	12,960	25,921	38,882	51,843	64,804	97,206	129,608
2′0″	1-16″	17,281	34,562	69,124	138,249	207,373	276,498	345,622	518,433	691,244
	⅛″	8,640	17,281	34,562	69,124	103,686	138,249	172,811	259,216	345,622
	¼″	4,320	8,640	17,281	34,562	51,843	69,124	86,405	129,608	172,811
2′6″	1-16″	21,601	43,202	86,405	172,811	259,216	345,622	433,028	648,042	864,056
	⅛″	10,800	21,601	43,202	86,405	129,608	172,811	216,014	324,021	432,028
	¼″	5,400	10,800	21,601	43,202	64,804	86,405	108,007	162,010	216,014
3′0″	1-16″	....	51,843	103,686	207,373	311,059	414,747	518,433	777,649	1,036,866
	⅛″	....	25,921	51,843	103,686	155,529	207,373	259,216	388,824	518,433
	¼″	....	12,960	25,921	51,843	77,764	103,686	129,608	194,412	259,216
3′6″	1-16″	....	....	120,967	241,935	362,902	483,871	604,838	916,257	1,209,677
	⅛″	....	....	60,483	120,967	181,951	241,935	302,419	458,128	604,838
	¼″	....	....	30,241	60,483	90,975	120,967	151,209	229,064	302,419
4′0″	1-16″	....	....	....	276,498	414,747	552,996	691,244	1,036,866	1,382,488
	⅛″	....	....	....	138,249	207,373	276,498	345,622	518,433	691,244
	¼″	....	....	....	69,124	103,686	138,249	172,811	259,216	345,622
5′0″	1-16″	....	....	....	....	518,434	691,245	864,056	1,296,084	1,728,112
	⅛″	....	....	....	....	259,217	345,622	432,028	648,042	864,056
	¼″	....	....	....	....	129,609	172,811	216,014	324,021	432,028

The limit to the resistance of any mass on the anvil is found at the pressure at which the metal will "flow" continuously. This pressure varies not only with the kind of metal, but also with every variation in the chemical composition, the physical structure or the form and method of support of the piece. For general use the value of this "modulus" may be taken at about the value of the shearing resistance of the material. For soft wrought iron, for example, it may be taken at about 50,000 pounds per square inch (3,515 kg. per sq. cm.) for moderately hard iron at a figure 20 per cent. higher, and for pure copper at about one-half the latter figure. There is, however, a great difference in the behavior of the two metals under pressure. The former has a distinct elastic limit in its original state which becomes "exalted," as was shown by the writer some ten years ago, when the piece is distorted, and becomes approximately equal to the maximum force, producing change of form, remaining permanently altered. The metal thus transformed does not yield subsequently to any less pressure. It will not flow under any pressure less than that which is required to produce distortion immediately upon its application. Copper, however, has no true and measurable elastic limit in its original condition as found in the market, and it does flow under the continued action of forces far less than those required to produce rapid and continuous distortion by steady pressure. A load which produces no visible effect when first applied will after a time be found to have caused a very decided, and often a very extensive, alteration of the form of the mass. This is also a now well-known property of some kinds of brass and of many other metals belonging to what the writer has called the tin class, to distinguish them from the metals of the iron and steel class, which do not exhibit this treacherous behavior. This difference is of some importance, not only as indicating the best method of working them, but also as showing that the first of these two classes is a safer class to deal with where the metal is to be used in the carrying of heavy and unintermitted stress than is the second class.

Another important distinction between these two classes is, as indicated by the results of investigations made by the writer, that the "iron class," which includes all the irons and all of the steels, offers more resistance as the rupturing action is slower, while the "tin class," which includes nearly all the other metals and very nearly all of the alloys that the writer has ever tested, yields the more readily the more slowly the distortion goes on. The second class is thus subject to that singular kind of change of form under heavy, continuous stress which is illustrated in the movement of all viscous solids—ice, for example, as seen in its flow in the glacier. This, it seems probable, may often occur under pressures far within those which are required to cause change of form in the testing machine in the ordinary methods of test. Iron has been found by Vicat, and later by the writer, to exhibit some such a phenomenon, but only when the pressures are considerably above one-half those usually found for the moduli of rupture, and this action is only seen in serious degree when the iron has been annealed and thus softened. Common merchant iron, so far as the writer is aware, does not show any tendency to such slow and imperceptible yielding under moderate loads.

The bearing of these facts upon the value of the drop press as a means of working iron and other metals into shape is obvious. Change of form can begin only when the elastic limit of the material is passed, and flow can progress steadily and uninterruptedly only when the pressure applied is in excess of the resistance of the metal in question to flow. The soft metals which belong to the "tin class" are best attacked by processes which cause a comparatively slow motion of their particles in changing form; iron and steel, on the contrary, being less resistant at high than at low velocities of flow, are best wrought by methods which produce rapid distortion. Professor Kick, of Prague, has shown very plainly that this difference in the amount of work demanded by the soft metals under the two kinds of treatment may amount to a very important quantity. He finds that the distortion of bodies by the action of the hydraulic press and by the action of a hammer dealing a succession of blows to produce the same change of form consume power in the ratio, in some cases, of one to ten. It is thus evident that the hammer or the drop is to be used for those special cases in which the pressures desired can not be reached by ordinary methods, and that it is best adapted to the working of iron and steel. The hydraulic press and automatic machinery are to be preferred where they can be conveniently and cheaply used. For much of the work that is now done in our smaller kinds of manufacturing, the drop has been shown by experience to be the only machine which will give the required enormous pressures and do the work rapidly and cheaply.

The maximum area of surface exposed to pressure which will be allowable for any given amount of compression can be determined approximately by dividing the total mean pressure due to the action of the drop with the given fall, and the proposed compression by the maximum resistance of the material. The maximum area which will permit any action upon the surface is to be ascertained by dividing the same maximum pressure due the fall of the drop by the elastic limit of the metal in compression.

The total work absorbed, or the resilience of the mass, up to the elastic limit is to be measured by multiplying the elastic resistance by one-half the precentage of compression which marks the elastic limit; the result measures the resilience in inch-pounds when the unit of measure is the inch, and in centimeter-kilograms when the units are metric. The total work done in any permanent change of shape is proportional to the volume affected and to the maximum resistance of the material to such deformation.

What figures shall be adopted for the resistance to be calculated upon in the production of flow in metals subjected to the action of the drop press is a question which the writer is unable to answer definitely. It would seem probable that the effect of the blow may be, in the case of cold metal, somewhat similar to that of cold-rolling, and, this being the case, the initial resistance to flow must be taken as at least 70,000 pounds per square inch (4,921 kg. per sq. cm.) and the resilience during flow at as high as 70,000 inch-pounds per cubic inch (4,921 kg. m., per cubic centimeter) for good common wrought iron. It may be safe to take the figure for hot iron, as usually wrought at less than one-half this amount. For copper the writer would, in the absence of exact data, take the work of deformation to be two-thirds that of iron for pieces of small section, and would expect a great increase of resistance with either metal when the surface acted upon by the drop becomes large in proportion to its thickness. Probably no very reliable figures can yet be given. Whatever the resistance may be, the drop will be very certain to overcome it, and the variation in its amount will simply determine how many blows must be struck to obtain a given amount of change of form.

Phosphorescent Paper.—The *Papier Zeitung* gives the following recipe for preparing a waterproof paper, which will shine in the dark: 10 parts water, 40 parts paper stock, 10 parts phosphorescent powder, 1 part gelatine, and 1 part bichromate of potash.—*Dingler's Journal*, November, 1882. C.

THE THEORY OF TURBINES.

[ABSTRACT.]

By Robert H. Thurston.

[Am. Soc. Mechanical Engineers: November Meeting, New York, 1883.]

1. Introduction.—The theory of whirl as given in some standard works and text-books on hydraulic machines, is partly based upon an hypothesis which is only approximately correct for a single rare case, and which is widely inaccurate for all usual forms of this class of "prime movers." The hypothesis here referred to assumes that the total effort of centrifugal force, and the work done by or against this force, are precisely the same whether the mass of water is at rest relatively to the wheel, as in a Whitelaw turbine, revolving with the orifices closed, or in motion, traversing the passages of the wheel, as in ordinary work; it further assumes that this action is the same whatever the motion, as to direction and velocity, relatively to the wheel.

The falsity of this hypothesis is obvious when it is considered that the action of centrifugal force is determined, not simply by the motion of the wheel itself, as previously assumed, but by the absolute motion of the water passing through the wheel. In the design of the turbine, it is easy to produce an indefinite variety of paths—in space—for the water sweeping through the wheel, and yet to secure maximum efficiency. This path may be made nearly straight in some forms of turbines with guides, and thus centrifugal action may be prevented; or the path may be a spiral of any desired class—as, for example, in "Barker's mill" or Segner's wheel—and centrifugal force thus made a maximum and the work done by or against that force is also a maximum.

These two thus form the limits between which all ordinary cases fall. In very many outward-flow turbines, having narrow crowns, the path of the water, in space, is so nearly rectilinear that the centrifugal action may be neglected. In fact, the best Boyden and Francis wheels have been designed without reference to the accelerating action of this force;* the form of bucket is such as to give a rectilinear path to the water, and the velocity and volume of discharge have been calculated as if no such acceleration occurs, and their high efficiency is a proof that such cases may be safely so treated. In inward-flow wheels, a class to which a very large proportion of the most successful wheels now constructed belong, this action is of importance.

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* Francis remarks: ". . . it is difficult to see how centrifugal force can operate in the important manner that is commonly assigned to it." Lowell Hydraulic Experiments, p. 42.

Since the energy gained or expended by centrifugal action is neither added to nor subtracted from the lost energy of the wheel, the rate of discharge into the tail-race being constant, as it may always be made by properly adjusting the speed of rotation of the wheel, it is evident that the efficiency of the wheel cannot be affected by it, and that it simply determines a change of the speed which produces the best effect. Thus, for example, were it possible to make two "reaction wheels" of the Scotch type, in one of which this action should be felt and in the other not, the speed of highest efficiency of the former would be infinite, while that of the latter would be finite, and yet the efficiencies of both wheels might, according to pure theory, be maxima.

In the outward flow turbines, as actually constructed, this modification of speed is practically unobservable and the effect of centrifugal action on the maximum of efficiency is still less perceptible, although the path, in space, of the water crossing the wheel is not rectilinear, but considerably curved. This is, however, largely a matter of design, and the engineer may easily so form his wheel-buckets, within tolerably wide limits, as to obtain a considerable or an inconsiderable centrifugal action. As the form of the bucket is the line of relative motion of the water and wheel, he may adopt any path and any law of variation of absolute angular and radial motion that he may find convenient or that he may desire, and, constructing the relative motion so obtained, obtain a form of bucket which will give the proposed motion in space.

2. Centrifugal force, in turbines, has the effect of causing a change in the head acting in the wheel to produce outflow at the orifices on the delivery side of the wheel and thus of producing a difference in the amount of actual energy stored in the issuing stream. This change of head causes an increase of velocity in the water flowing through the wheel-passages of outward-flow wheels, a decrease in inward-flow, and no change in parallel-flow wheels; it thus is measured by a head which is deducted from the total head driving the first class and is added to that driving the second class of wheels, the final velocity being the same; or, the head-race level being the same, and

the orifices unchanged in area, the effect is to increase the head at the orifice, or to diminish it, as the case may be, and thus to cause acceleration or retardation of flow. This action has a useful regulating effect in the inward-flow wheel and a disturbing action in the outward-flow turbine.

3. The magnitude of the total effect varies with the extent to which the water partakes of the rotation of the wheel, being a maximum, as already stated, where they have the same angular motion, and becoming zero when the path of the fluid in space is made rectilinear; it may have any intermediate value.

As shown in all works on mechanics, the acceleration due to centrifugal force is

$$f = \frac{v^2}{r} = a^2 r \qquad (1.)$$

where v, r, and a are respectively the linear velocity, the radius, and the angular velocity of the particle in its orbit. This dynamic measure, f, of centrifugal force is so related to the static measure, F, of its effort and to the weight, W, that

$$\frac{F}{W} = \frac{f}{g};\ F = Mf = \frac{W}{g} a^2 r \ \therefore F = 2\,\frac{Wv^2}{r\,2g} = \frac{2}{r} Wh \qquad (2.)$$

when g and h are the acceleration of gravity and the height due the velocity, v. Then

$$F = W\frac{v^2}{rg} = Wr\frac{4\pi^2 r}{gt^2} = 1{\cdot}224\,W\frac{r}{t^2} = 0{\cdot}00034 N^2 Wr$$

if $N =$ revolutions per minute, $t =$ time of one revolution in seconds; this is a useful standard equation.

4. The work of centrifugal force is easily determined when the law of variation of v with r is known. Thus $F = \frac{W}{g} a^2 x$ and the work done by or against F in transit from one point to another along any line, having angular motion, a, is

$$U = \int F dx = W\frac{a^2}{g}\int_{x_1}^{x_2} x dx = W\frac{a^2}{2g}(x_2^{\,2} - x_1^{\,2}) \qquad (3)$$

When $x = r$,

$$U = \frac{W}{2g}(v_2^{\,2} - v_1^{\,2}) \qquad (4)$$

when v_1 and v_2 are the linear velocities, initial and final.

Again, when a body enters upon any path, in a revolving system, with an initial velocity, V_1, relative to that system, and leaves with a relative velocity, V_2, no other force acting upon it than the deviating centrifugal force, the change of energy will be due to the action of that force and will measure the work done by it. Then

$$W\frac{V_2^2 - V_1^2}{2g} = W\frac{v_2^2 - v_1^2}{2g};\quad V_2^2 - V_1^2 = v_2^2 - v_1^2.$$

$$V_2 = \sqrt{(v_2^2 - v_1^2 + V_1^2)} = \sqrt{[V_1^2 + a^2(r_2^2 - r_1^2)]} \qquad (5)$$

The energy gained is

$$U_2 - U_1 = W\frac{V_2^2 - V_1^2}{2g}$$

and the head, h_c, to which the change is due

$$h_c = \frac{V_2^2 - V_1^2}{2g} = \frac{a^2}{2g}(n^2r_1^2 - r_1^2) = (n^2 - 1)\frac{a^2r_1^2}{2g} \qquad (6)$$

when $n = \frac{r_2}{r_1}$.

5. First case.—The maximum possible work of centrifugal action in any form of turbine is thus found to be

$$U_c = W(n^2 - 1)\frac{a^2r_1^2}{2g} = DQ\frac{a^2r_1^2}{2g}(n^2 - 1) \qquad (7)$$

if D and Q are the specific heaviness and the volume of water flowing through the wheel per second.

The coefficient, $(n^2 - 1) = f(n)$, will be of frequent occurrence in later equations.

The head, $(n^2 - 1)\frac{a^2r_1^2}{2g} = h_c$, accelerates outward and retards inward flow, since $n^2 - 1$ is positive for outward and negative for inward-flow wheels, and the head at the penstock must be

$$h = h_1 - h_c \text{ and } h_1 = h + h_c \qquad (8)$$

if h_1 is the head due the velocity of outflow through the exit orifices when h is the head due the energy at entrance.

6. A second case in which the linear velocity of rotation, v, diminishes uniformly, as the water traverses the wheel, is that probably most usually illustrated in turbines. When the wheel is driven at the speed of maximum efficiency, this velocity becomes zero at the exit and the motion of the issuing current is simply radial. Then

$$v = \frac{r_2 - r}{r_2 - r_1}\, v_1;\; v^2 = \left(\frac{r_2 - r}{r_2 - r_1}\right)^2 v_1^2 = \left[\frac{n - \dfrac{r}{r_1}}{n - 1}\right]^2 v_1^2;$$

and $$DQh_e = \frac{DQ}{g}\int_{r_1}^{nr_1} \frac{v^2}{r}\, dr = \frac{2DQ}{(n-1)^2}\, \frac{v_1^2}{2g} \int_{r_1}^{nr_1} \left(n - \frac{r}{r_1}\right)^2 \frac{dr}{r}\,;$$

$$= \frac{2DQ}{(n-1)^2}\, \frac{v_1^2}{2g}\, [2n^2 \log_e n - 4n(n-1) + n^2 - 1]\,; \quad (9)$$

$$h_e = \frac{2v_1^2}{2g(n-1)^2}\, [2n^2 \log_e n - 4n(n-1) + n^2 - 1] = \frac{v_1^2}{2g} f(n) \quad (10)$$

Here, as before, the coefficient of the quantity $\frac{v_1^2}{2g}$, which measures the head due the initial velocity of whirl v_1 is simply a function of n.

7. A third case is that in which the *energy*, instead of the velocity of rotation, of the particle is given a uniform increment or decrement, *i. e.*, $d\left(\frac{v_1^2}{2g}\right)$ = constant instead of dv = constant. This case is less frequently met with than the last, but is probably not infrequently approximated in practice. Then

$$v^2 = \frac{r_2 - r}{r_2 - r_1}\, v_1^2 = \frac{n - \dfrac{r}{r_1}}{n - 1}\, v_1^2\,;$$

$$DQh_e = \frac{2DQ}{n-1}\, \frac{v_1^2}{2g} \int_{r_1}^{nr_1} \left(n - \frac{r}{r_1}\right) \frac{dr}{r}\,;$$

$$= 2DQ\, \frac{v_1^2}{2g} \left(\frac{n}{n-1} \log_e n - 1\right) \quad (11)$$

and $$f(n) = 2\left(\frac{n}{n-1} \log_e n - 1\right) \quad (12)$$

This adjustment of velocities produces considerably greater values of $f(n)$ than the preceding, and is, therefore, probably more desirable for inward-flow wheels.

8. Other methods of variation of v may be adopted by the hydraulic engineer, as, for example, $v = v_1$ = constant, when flow varies,

$$DQh_e = 2DQ\, \frac{v_1^2}{2g} \int_{r_1}^{nr_1} \frac{dr}{r} = DQ\, \frac{v_1^2}{2g}\,.\; 2 \log_e n \quad (13)$$

and $$f(n) = 2 \log_e n. \quad (14)$$

8. Numerical values of $N = f(n)$ are given in the following tables for each of the above cases:

TABLE I.

Values of $f(n)$ in Equation 7.

$v \propto r$.

n	$f(n)$	n	$f(n)$
0·1	—0·99	1·1	+ 0·21
0·2	—0·96	1·2	+ 0·44
0·3	—0·91	1·3	+ 0·69
0·4	—0·86	1·4	+ 0·98
0·5	—0·75	1·5	+ 1·25
0·6	—0·64	1·6	+ 1·56
0·7	—0·51	1·7	+ 1·89
0·8	—0·36	1·8	+ 2·24
0·9	—0·19	1·9	+ 2·61
1·0	—0·00	2·0	+ 3·00

TABLE II.

Values of $\frac{1}{2} N$ in Equation 9.

$dv =$ constant; $v \propto (r_2 - r)$

n	$f(n)$	n	$f(n)$
0·1	—0·834632	1·1	+ 0·065068
0·2	—0·701180	1·2	+ 0·127148
0·3	—0·585133	1·3	+ 0·186570
0·4	—0·481147	1·4	+ 0·243569
0·5	—0·386294	1·5	+ 0·298374
0·6	—0·298715	1·6	+ 0·351157
0·7	—0,217129	1·7	+ 0·402104
0·8	—0·110578	1·8	+ 0·451338
0·9	—0·068117	1·9	+ 0·498993
1·0	—0·000000	2·0	+0·545175

TABLE III.

Values of N in Equation 11.

$d\,(v^2) = \text{constant}; \ v \propto (r_2 - r)^{\frac{1}{2}}$.

n	$f(n)$	n	$f(n)$
0·1	—1·488314	1·1	+ 0·096824
0·2	—1·195281	1·2	+ 0·187858
0·3	—0·969802	1·3	+ 0·273824
0·4	—0·778279	1·4	+ 0·355305
0·5	—0·613706	1·5	+ 0·432791
0·6	—0·467523	1·6	+ 0·506686
0·7	—0·335553	1·7	+ 0·517337
0·8	—0,214850	1·8	+ 0·645040
0·9	—0·103509	1·9	+ 0·710049
1·0	—0·000000	2·0	+ 0·772589

TABLE IV.

Values of N in Equation 13.

$v = v^1$ constant.

n	$f(n)$	n	$f(n)$
0·1	—4·6052	1·1	+ 0·1906
0·2	—3·2189	1·2	+ 0·3646
0·3	—2·4180	1·3	+ 0·5241
0·4	—1·8326	1·4	+ 0·6629
0·5	—1·3863	1·5	+ 0·8109
0·6	—1·0217	1·6	+ 0·9400
0·7	—0·7134	1·7	+ 1·0612
0·8	—0·5463	1·8	+ 1·1055
0·9	—0·2107	1·9	+ 1·2837
1·0	—0·0000	2·0	+ 1·3863

9. A Turbine consists of a pair of cylindrical rings or flat annular bands revolving about an axis, usually horizontal but often vertical, and connected by curved buckets or vanes. It differs from the older forms of wheels in the fact that the water passes *through* the wheel,

the buckets having two openings, the one for entrance and the other for exit, while in the other forms of water wheel, the buckets have but a single opening, the water entering and leaving by the same orifice. The turbine is also distinguished by the method of transfer of energy from water to wheel. In the old forms of wheel, the fluid acts by weight, as in overshot and breast-wheels, or by impulse and later reversion with reaction, as in the Poncelet form of undershot; while, in turbines, the transfer is never by weight and is usually principally due to impulse and reaction without reversal of relative motion.

10. The Action of the Turbine is substantially the same in all its forms. A current of water flowing from under a certain head, with a velocity which in some cases is that due the total head, as in the "turbines of free deviation," and sometimes to a part of that head only, as in pressure turbines, is given a certain lateral direction or whirl, such that the energy of direct flow becomes but a small fraction of the total energy of the fall, and this whirl is then taken up and its energy given out upon the wheel which only permits its discharge, if working correctly, when all energy of whirl has been applied to drive the wheel and when the energy of direct flow has been made a minimum.

The resultant motion of water and wheel is that of the current on the wheel, and the absolute motion of the stream may be made whatever the engineer may desire, within certain limits, by making the path on the wheel such as, at the best speed of the turbine, shall produce that motion. The character of this motion, while the available energy of the fall is being taken up by the wheel, is usually determined either by custom or by the individual preference of the designer. It is properly determined by the character of the wheel which is to be designed. Generally, in outward-flow wheels, the path of the water in space, while traversing the wheel-buckets, should be nearer rectilinear than in inward flow wheels in order that the action of centrifugal force produced by the whirl should disturb the former as little, and assist in regulating the latter as much as possible. The paths of the current in space and on the wheel may be obtained either by the generally rough empirical methods which are given in the older treatises on turbines and are usually practised in the drawing office, by more exact graphical construction, or by precise construction from the equations of the curves representing those paths as given later in this paper.

11. Friction in the guide passages and bucket-channels causes a loss of a notable part of the energy of the fall.

For any given style of turbine, its amount may be readily estimated and as nearly correctly as is practically important. Calling the whole head H, and the head lost by friction h_f, the remaining usefully applicable part of the head will be

$$h_1 = H - h_f \tag{15}$$

In the following treatment, it will be assumed that the friction-waste is thus accounted for and the theory of the turbine will be developed without regard to this loss, considering the head acting on the turbine to be simply h_1.

12. Ineffective guidance is sometimes a cause of serious loss of energy. This occurs when the passages are so large in cross section, so short and so sharply curved, that the stream, instead of following closely and in full volume, the line of the bucket or guide-curve, flows more nearly straight across from entrance to exit, in a smaller stream, and leaves the sharp turns in the curve filled with a mass of eddying water, which does not move through the channel with the full velocity demanded in efficient working. This is an effect of sharply curved passages in wheels having an insufficient number of buckets or guides. The best wheels have a sufficient number of guides and buckets to prevent this loss, while they have no more than is really necessary, and are therefore not subject to excessive loss by friction. It will be here assumed that this loss may be neglected.

13. Final radial or axial flow produces a loss which is, to a certain extent, unavoidable, as the discharged water must be thrown into the tail-race, with enough velocity to carry it clear of the wheel, and must have so much velocity in the wheel, in direct flow, that the desired power may be obtained, and the necessary volume of water worked off to produce that power, without adopting too large a wheel; excessive size not only causes increase of cost of wheel and attachments, but also an increase of loss by friction of mechanism. The magnitude of this necessary waste is determined by the designer, by reference to the results of experience, or by his judgment after studying the proposed location and the conditions under which the wheel is to be operated; it varies usually from two to ten per cent. of the total energy of fall, according to size of wheel and to circumstances surrounding it.

Final whirl is usually intended to be either zero or so nearly zero that this waste of energy may be neglected.

14. Regulation is generally secured in turbines by the use of an adjustable "gate," or equivalent, which, usually under the control of some form of powerful governor, adjusts the flow of water to the demand of the load.

In nearly all cases, the partial closing of the gate results in a partial contraction of the stream entering the wheel, or the guide curves, and a consequent loss of head, which is often a serious tax upon the efficiency of the wheel. In the turbine of usual form, in which the current enters the wheel under pressure, and in which the bucket channels must be kept full to give maximum efficiency, the gradual closing of the regulator causes a gradual reduction of pressure in the wheel, and thus, at some point, converts it into an impulse and reaction wheel without pressure, and the velocity of exit from the guides at the same time becomes more nearly that due to the total head, h_1. This change in the method of operation of the wheel leads to a waste of energy, also, as it compels the working of the wheel at a wrong speed and under conditions for which it was not designed. An advantage which often partly compensates this defect, however, is that the range of regulator motion through which the usually experienced variation of power demanded carries the wheel, is somewhat extended and regulation is thus made easier; this occurs by the increasing velocity of flow V_1, as the pressure in the wheel is reduced while the regulator is closing, and *vice versa;* the tendency is thus to regulate, by decreasing the volume of flow rather than the working head, h_1.

In the theory of the operation and the efficiency of the turbine, it is assumed that the wheel is working at full gate. Where a large but uniform amount of power is demanded, the great loss of efficiency thus met with in some classes of wheels can be reduced by putting in two or more wheels, one only of which is regulated, the other or others being worked at full gate, and thrown off or on as may be necessary, one by one.

15. The Pure Theory of Turbines is very simple, and the principles of their construction are easily deduced therefrom. Neglecting the action, for the present, of centrifugal force and the losses by friction, the action of the regulator and other causes of waste which are more or less avoidable, it is easy to derive expressions for maximum efficiency, and from them to deduce principles guiding the engineer in their design and construction.

In all cases the efficiency is

$$E = DQ\,(h_1 - h_2) \div DQh_1 = \frac{h_1 - h_2}{h_1}. \qquad (16)$$

where

$D =$ the heaviness of water;
$Q =$ the volume of water flowing per second;
$h_1 =$ the head in the supply chamber;
$h_2 =$ the total loss of head.

In DQh_2 may be included all losses of energy, whether by leakage, friction, or final flow. It is evident that it is a matter of indifference, which form or type of wheel is adopted, so far as its efficiency is concerned, provided that these losses are reduced to the same minimum. All wheels of the same type will, theoretically, have the same efficiency, if designed with the same angle of discharge, β, and for the same velocity of final outflow.

Since the form of wheel is, to a certain extent, a matter of indifference, and an infinite variety of wheels may in theory be made to give the same efficiency, it is evident that it will be necessary, in order to ascertain the proportions of parts, to study the special types of wheel proposed to be used in order to ascertain the values of h_1 the total head driving the wheel, and especially of h_2, the loss of head, and thus to determine for each case the principles involved in the correct method of working for high efficiency.

The value of the maximum efficiency of certain types of wheel can be written out at once in certain cases. Of the total energy reaching the wheel, when revolving at that speed which reduces final whirl to zero, none is lost, except that of final direct flow. If β is the exit angle of the wheel bucket, reckoned between the tangent and the line of flow, the velocity of final flow is, in the "turbine of Whitelaw," $V \sin.\beta$; the lost energy is $DQV^2 \sin.^2\beta \div 2g$; the energy of the fall is $DQ\frac{V^2}{2g}$, and the efficiency is

$$E = DQ\left(\frac{V^2 - V^2 \sin.^2\beta}{V^2}\right) = 1 - \sin.^2\beta = \cos.^2\beta \qquad (17)$$

For certain cases in which the head giving whirl is divided, as in the parallel flow wheel, the one half producing the flow from the guides, the other half causing acceleration in the wheel and final relative whirl, the efficiency is obviously

$$E = \frac{DQ\,(h_1 - h_2)}{\frac{DQ}{2}(h_1 - h_2) + \frac{DQ}{2}(h_1 - h_2)\sec.^2\beta} = \frac{2}{1 + \sec.^2\beta}$$

$$= \frac{2}{2 + \tan.^2\beta} \qquad (18)$$

It is seen that when a wheel is turning at the best speed, the efficiency depends solely upon the magnitude of the angle of discharge, β, and that the lost energy is simply that of final direct flow, and that the efficiency approaches unity as β approaches zero. It is further seen that, as the speed can always be adjusted as to prevent loss of energy by final whirl, the study of types and forms is principally important as affording a means of ascertaining the method of division of head and the probably best velocity of rotation.

The following treatment is, for the reasons above indicated, directed to the cases of simple types of wheel and to a general discussion relating to the case usually met with in works on this subject.

16. The turbine of uniform direct flow is one to which analysis can be readily applied, and one from the theory of which the most general and instructive conclusions can be deduced. In this wheel, that component of the motion which takes the water into and through the wheel is uniform and equal to the velocity of final direct flow, and the whirl which constitutes the other component is usully varied, as the stream traverses the wheel, according to a very simple law. This uniformity of direct flow is secured in the parallel-flow wheel by making the wheel of equal diameters from receiving to discharging side, and in other wheels by making the depth between crowns vary inversely as the radius, if we neglect the thickness of the buckets, which, however, must be allowed for in designing.

It follows that, in this wheel, if

$n =$ the ratio $\frac{r_2}{r_1}$ of the radii,

$\alpha =$ the terminal angle between the guides and tangent,

$\beta =$ the angle of discharge, as above,

$u =$ velocity of direct flow,

Since $Q = Au =$ constant and $u =$ constant, tan. $\alpha = n$ tan. β; for the velocity of relative whirl, v_2, at β must be equal to nv_1, n times the whirl at exit from the guides, v_1, and the areas of passages normal to the whirl are inversely as these velocities of whirl, provided that the speed of wheel at the receiving side is equal to the whirl of the entering water. Then

$$v_1 = u \div \tan. a; \; v_2 = u \div \tan. \beta \tag{19}$$

$$v_2 = nv_1 = \frac{u}{\tan.\beta} = \frac{nu}{\tan.a}$$

and, as stated above,

$$\tan. a = n \tan. \beta \tag{20}$$

The velocities of the wheel, at the inner and the outer periphery, are

$$w_1 = ar_1; \; w_2 = ar_2 = nar_1 \tag{21}$$

where

w_1 = velocity of whirl of receiving side of wheel,
w_2 = velocity of whirl of discharging side of wheel,
a = angular velocity of the wheel,
r_1, r_2 = the radii.

Evidently, when working properly,

$$v_1 = ar_1; \; v_2 = nar_1 = ar_2 \tag{22}$$

In this wheel, so adjusted, the motion of each particle is uniform along a radial line, which line rotates about the centre of the wheel at such a rate that the linear velocity of whirl is uniformly diminished from a maximum at entrance, and becomes zero at its exit from the wheel.

17. The theory of the turbine of uniform direct flow is best constructed by considering the distribution of energy usefully and wastefully, and deducing a value for the expression*

$$E = \frac{h_1 - h_2}{h_1}$$

The total energy expended is that due to the head, h_1; it is obtained thus (centrifugal action being at present neglected):

(*a*) Energy of initial whirl, $DQ \frac{v_1^2}{2g}$; head, $\frac{v_1^2}{2g} = h'$;

(*b*) Energy of initial flow, $DQ \frac{u^2}{2g}$; head, $\frac{u^2}{2g} = h''$;

(*c*) Energy of reversed whirl in the wheel, $DQ \frac{v_2^2}{2g}$; head, $\frac{v_2^2}{2g} = h'''$.

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* This form of wheel is that studied by Rankine (Prime Movers, Part II, Chap. VI).

The last item is the energy gained in the wheel buckets, due to the difference of pressure at the entrance and exit sides, when the wheel is at the best speed. When not at this speed, this energy becomes

$$(c')\ DQh''' = \frac{DQ}{2g}\left[v_2^2 - (v_1 - ar_1)^2\right]$$

$$= \frac{DQ}{2g}\left[n^2 v_1^2 - (v_1 - ar_1)^2\right]$$

The energy, $\frac{DQ}{2g}(v_1 - ar_1)^2$ must be reckoned with other lost work.

The total energy expended is, for the last, or general, case.

$$(A)\quad D\,Q\,h_1 = \frac{D\,Q}{2g}\left(h' + h'' + h'''\right)$$

$$= \frac{D\,Q}{2g}\left[n^2 v_1^2 (1 + \tan.^2 \beta) + 2a\,r_1\,v_1 - a^2 r_1^2\right] \qquad (23)$$

since $u^2 = n^2 v_1^2 \tan.^2 \beta$.

The effective energy is obtained by deducting from the above the lost energy: this consists of

(*e*) Energy of final flow, $\frac{D\,Q}{2g} u^2 = \frac{D\,Q}{2g} n^2 v_1^2 \tan.^2 \beta$

(*f*) Energy of final whirl, $\frac{D\,Q}{2g}(v_2 - n\,a\,r_1)^2 = \frac{D\,Q}{2g}[n(v_1 - ar_1)]^2$

and the total waste is

$$(B)\ D\ Q\,h_2 = \frac{D\,Q}{2g}[n^2 v_1^2 (1 + \tan.^2 \beta) - 2\,an^2 r_1\,v_1 + n^2 a^2 r_1^2] \qquad (24)$$

and when the energy due the quantity $v_1 - ar_1$ is lost, we also have a waste,

(*g*) Energy wasted at entrance, $\frac{D\,Q}{2g}(v_1 - ar_1)^2$

The total effective energy is

$$(A) - (B) = \frac{D\,Q}{2g}(n^2 + 1)(2ar_1\,v_1 - a^2 r_1^2) \qquad (25)$$

The efficiency is, for the case taken,

$$E = \frac{(A) - B)}{(A)} = \frac{(n^2 + 1)(2ar_1 v_1 - a^2 r_1^2)}{n^2 v_1^2 (1 + \tan.^2 \beta) + 2ar_1 v_1 - a_2 r_1^2} \qquad (26)$$

The maximum efficiency is evidently obtained when the wheel is at its normal speed and the loss by whirl is a minimum; and this, as is seen by inspection, occurs when

$$v_1 = ar_1 \tag{27}$$

When $v_1 = ar_1$; $v_2 = nv_1 = nar_1 = nr_2$, and

$$E_{\text{max.}} = \frac{n^2 + 1}{n^2 \sec.^2 \beta + 1} = \frac{n^2 + 1}{n^2(1 + \tan.^2 \beta) + 1} \tag{28}$$

For the parallel flow turbine, $n = 1$, and the general equation for E becomes

$$E = \frac{4ar_1v_1 - 2a^2v_1^2}{v_1^2 \sec.^2 \beta + 2ar_1v_1 - a^2r_1^2} \tag{29}$$

$$E_{\text{max.}} = \frac{2}{\sec.^2 \beta + 1} = \frac{2}{2 + \tan.^2 \beta} \tag{30}$$

The limit of maxima is approached as β approximates to zero; this limit is unity for all cases.

The case of the turbine of parallel flow above, is an example of the equal division of head, $h_v = \frac{v_1^2}{2g} + \frac{v_2^2}{2g} = 2\frac{v_1^2}{2g}$, since $v_1 = v_2$; and this form of turbine, with uniform axial flow, other things equal, is therefore probably that least subject to loss of energy by friction.

18. Numerical Values of the maximum efficiency of turbines of uniform direct flow are as follows, for the most usual cases in which, for the outward, the inward, and the parallel flow wheels, respectively, $\frac{r_2}{r_1}$ is taken equal to $n = 1{\cdot}41$, $n = 0{\cdot}50$; $n = 1$.

EFFICIENCY OF TURBINES.

Outward Flow, $n = 1{\cdot}41$.		Inward Flow, $n = 0{\cdot}50$.		Parallel Flow, $n = 1$.	
β	$E_{\text{max.}}$	β	$E_{\text{max.}}$	β	$E_{\text{max.}}$
10°	0·980	10°	0·994	10°	0·985
15°	0·955	15°	0·986	15°	0·968
20°	0·918	20°	0·975	20°	0·939
25°	0·872	25°	0·958	25°	0·901
30°	0·819	30°	0·866	30°	0·856

For the "Reaction Wheel" of the usual form, in which β can be made o without causing difficulty either of construction or operation, we have

$$E_{\text{max.}} = 1.$$

Comparing the above figures it is seen that for equal values of β, the inward flow wheel is most efficient; but it is not possible to adopt as small values of β in this wheel as in the outward flow; in practical work it may usually be assumed that n tan. $\beta = a$ may be made the same for all classes of wheel, although this value may be made slightly smaller in the inward flow wheel which has a slight advantage in this respect. The values below may be taken as usual for good wheels; they are often considerably greater. The apparent defect of efficiency in the inward flow wheel is compensated by its smaller size and less friction, and often, by the use of a "draught tube."

$n = 1·41$	$n = 1$	$n = 0·50$
$a =$ 14° — 20° $\beta =$ 10° — 14° $E = 0·980 — 0·965$	$a =$ 14° — 20° $\beta =$ 14° — 20° $E = 0·988 — 0·975$	$a =$ 14° = 20° $\beta =$ 20° — 30° $E = 0·98 — 0·87$

19. The total head acting on any wheel in which the whirl v_1 and the velocity of rotation, a_1 are fixed, has been found to be

$$h_1 = (n^2 v_1^2 \sec.^2 \beta + 2ar_1 v_1 - a^2 r^2) \div 2g. \tag{31}$$

The expression, when v_1 is constant and efficiency a maximum, gives $ar_1 = v_1$ and

$$2gh_{1\ \text{min.}} = n^2 v_1^2 \sec.^2 \beta + a^2 r_1^2 = (n^2 \sec.^2 \beta + 1). \tag{32}$$

When $a = o$ the wheel becoming fixed,

$$2gh_1 = n^2 v_1^2 \sec.^2 \beta = v_2^2 \sec.^2 \beta. \tag{33}$$

and the whole energy of fall is wasted, the water issuing from the wheel with the velocity due the whole head, less that lost by friction, while the effort exerted on the wheel becomes a maximum.

20. The ratio, $\frac{ar_1}{\sqrt{2gh_1}}$, of the velocity, ar_1, of the receiving side of the wheel to the velocity due the head, $\sqrt{2gh_1}$, is, at maximum efficiency,

$$Z_1 = \frac{ar_1}{\sqrt{2gh_1}} = \frac{1}{\sqrt{(n^2 \sec.^2 \beta + 1)}} \tag{34}$$

which becomes, for parallel flow wheels,

$$Z_1 = \frac{1}{\sqrt{(\sec.^2 \beta + 1)}} = \frac{1}{\sqrt{(2 + \tan.^2 \beta)}} \tag{35}$$

and hence, in the parallel flow wheel, in which $n = 1$,

$$*E_{\max.} = \frac{2}{\sqrt{(2 + \tan.^2 \beta)}} = 2z_1^2 \tag{36}$$

For $\beta = 30° = \alpha$, Morin finds, by test of this kind of wheel, $z_1 = 0.65$; the above expression gives $z_1 = 0{\cdot}66$.

The value of z', the ratio of the velocity of the delivery side of the wheel to that due the head is determined by the design of the wheel; in these wheels, $z' = n\, z_1$, and

$$Z^1 = \frac{n\,a\,r}{\sqrt{{}^1gh,}} = \frac{n}{\sqrt{n^2 \sec.^2 \beta + 1}} = \frac{n}{\sqrt{n^2 + n^2 \tan.^2 \beta + 1}} \tag{37}$$

which, when $n = 1$, gives

$$Z^1 = \frac{a\,r_2}{\sqrt{2gh}} = \frac{1}{\sqrt{2 + \tan^2 \beta}} \tag{38}$$

as before, and

$$E_{\max.} = \frac{n^2 + 1}{n^2 \sec^2 \beta + 1} = \frac{n^2 + 1}{n^2} Z_1^2 \tag{39}$$

$$Z^1 = \frac{n\sqrt{E}}{\sqrt{n^2 + 1}} \tag{40}$$

This result is only correct for the class of wheels here treated of, in which the direct flow is uniform and $\tan \alpha = n \tan \beta$.

21. The division of the total head into the two parts producing, respectively, velocity in the guides and pressure and acceleration in the wheel may now be easily determined for best effect.

Neglecting the energy of direct flow, which is fixed by the designer in accordance with known conditions of working, the remaining energy of the fall takes effect in producing whirl in the guides and a reversed whirl in the wheel; the total is

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* Rankine finds this result accordant with Morin's experiment; but he deduces this expression for "all turbines with guide-blades" (Prime Movers, pp. 195, 196), which is manifestly incorrect.

$$U_w = DQ\,\frac{(n^2+1)\,v_1^{\,2}}{2g} \tag{41}$$

Of this, one part, $h_a = DQ\,\frac{v_1^{\,2}}{2g}$ is that of initial whirl and the other part, $h_b = D\,Q\,\frac{n^2 v_1^{\,2}}{2g}$, is that of reversed relative whirl in the wheel; they thus have the relation,

$$\frac{1}{n^2+1} : \frac{n^2}{n^2+1} = 1 : n^2. \tag{42}$$

22. The "turbine of free deviation," or turbine without pressure, is another typical case which, if radial flow be uniform, can be treated by an equally simple method. In this turbine the water escapes from the guides, with the full velocity due the head, into a wheel in which there is no pressure in the buckets. In this case the total energy of the fall is developed as kinetic energy at entrance into the wheel, and is there gradually converted into useful work, the relative whirl becoming a maximum, and the absolute whirl a minimum, at exit from the buckets.

Then we have

Total Energy Expended:

Initial whirl, $DQ\,\frac{v_1^{\,2}}{2g}$.

Initial flow, $DQ\,\frac{u^2}{2g} = DQ\,\frac{v_1^{\,2}\tan.^2 a}{2g}$.

(*A*) Total, $$DQ\,\frac{v_1^{\,2}\sec.^2 a}{2g}. \tag{43}$$

(*B*) *Energy Wasted:*

Final flow, $$DQ\,\frac{v_1^{\,2}}{2g}\tan.^2 a \tag{44}$$

Final whirl, O.

Effective Energy: $$(A) - (B) = \frac{DQ}{2g}\,v_1^{\,2} \tag{45}$$

Efficiency: $$E_{\max} = \frac{(A)-(B)}{(A)} = \frac{1}{\sec.^2 a} = \cos.^2 a \tag{46}$$

which approaches unity as a approaches 0.

At the speed of maximum efficiency, when final whirl is o,

$$ar_2 = nar_1 = v_1 - ar_1,$$

since the relative motion, $v_1 - ar_1$, along the bucket, remains unchanged and the only force acting upon the stream is a deviating force. Also, neglecting direct flow and centrifugal action, as before,

$$v_1 = (n + 1)\, ar_1;\ ar_1 = \frac{v_2}{n} = \frac{v_1}{n+1} = w_1;$$

$$z^1 = \frac{v_2}{v_1} = \frac{n}{n+1}, \text{ nearly.} \tag{47}$$

when $n = 1$,

$$w_2 = ar_2 = v_2 = \tfrac{1}{2} v_1 = \tfrac{1}{2}\sqrt{2gh_1}, \text{ nearly.} \tag{48}$$

$$Z^1 = \frac{v_2}{\sqrt{2gh_1}} = \tfrac{1}{2} \tag{49}$$

In these, as in all wheels, the receiving edge of the bucket should make with the tangent to the wheel the angle

$$\delta = \frac{v_1 - w_1}{u} = \frac{nv_1}{u(n+1)}; \tag{50}$$

The angle of discharge, β, is so made that direct flow shall be uniform. It is not true that, for this wheel, n tan. $\beta =$ tan. α, since the whirl of the wheel, w_1, is not equal to that of the water, v_1; but, for all these wheels,

$$v_2 \tan. \beta = v_1 \tan. \alpha;\ \tan. \beta = \frac{v_1}{v_2} \tan. \alpha \tag{51}$$

23. The general theory of these turbines is easily constructed when the form of wheel is determined, and its elements can be expressed algebraically. Thus, let the velocities of whirl have any relation, *e. g.*, such that

$$v_2 = mnv_1; \tag{52}$$

In this case, a wheel of uniform direct flow will have such a speed that

$$w_1 = ar_1 = mv_1;\ w_2 = ar_2 = nar_1 = mnv_1 = v_2 \tag{53}$$

and the angle β must be of such magnitude that

$$\tan. \alpha = mn \tan. \beta \tag{54}$$

and the angle δ such that

$$\tan. \delta = \frac{v_1 - w_1}{u} = \frac{v_1(1 - m)}{u} \tag{55}$$

Then it follows that the

Total Energy Expended is

Initial whirl, $DQ\,\dfrac{v_1^2}{2g}$;

Initial flow, $DQ\,\dfrac{v_1^2 \tan.^2 a}{2g} = \dfrac{v_1^2 m^2 n^2 \tan.^2 \beta}{2g}$

Gained in the wheel, $DQ\,\dfrac{n^2 m^2 v_1^2 - (v_1 - a r_1)^2}{2g}$

$$(A)\ \textit{Total},\ DQh_1 = \frac{DQ}{2g}\left(n^2 m^2 v_1^2 \sec.^2 \beta + 2 a r_1 v_1 - a^2 r_1^2\right) \qquad (56)$$

Energy Wasted:

Final flow, $DQ\,\dfrac{m^2 n^2 v_1^2 \tan.^2 \beta}{2g}$;

Final whirl, $DQ\,\dfrac{(m n v_1 - n a r_1)^2}{2g}$;

$$(B)\ \textit{Total},\ DQh_2 = \frac{DQ}{2g}\left(m^2 n^2 v_1^2 \sec.^2 \beta - 2 a m n^2 r_1 v_1 + n^2 a^2 r_1^2\right) \qquad (57)$$

Efficiency:

$$E = \frac{(A) - (B)}{(A)} = \frac{h_1 - h_2}{h_1};$$

$$= \frac{2 a r_1 v_1 - a^2 r_1^2 + 2 a r_1 m n^2 v_1 - n^2 a^2 r_1^2}{m^2 n^2 v_1^2 \sec.^2 \beta + 2 a r_1 v_1 - a^2 r_1^2} \qquad (58)$$

When $m = 1$, this expression reads

$$E = \frac{2 a r_1 v_1 - a r_1^2 + 2 a n^2 r_1 v_1 - n^2 a^2 r_1^2}{n^2 v_1^2 \sec.^2 \beta + 2 a r_1 v_1 - a^2 r_1^2} \qquad (59)$$

For best work, $m v_1 = a r_1$; tan. $a = mn$ tan. β, and

$$E_{\text{max.}} = \frac{2 m v_1^2 - m^2 v_1^2 + m^2 n^2 v_1^2}{m^2 n^2 v_1^2 \sec.^2 \beta + 2 m v_1^2 - m^2 v_1^2} \qquad (60)$$

and, when $m = 1$ and tan. $a = n$ tan. β,

$$E_{\text{max.}} = \frac{v_1^2 + n^2 v_1^2}{n^2 v_1^2 \sec.^2 \beta + v_1^2} = \frac{n^2 + 1}{n^2 \sec.^2 \beta + 1}; \qquad (61)$$

as already deduced for the previously discussed form of pressure turbine, centrifugal action neglected.

(To be continued.)

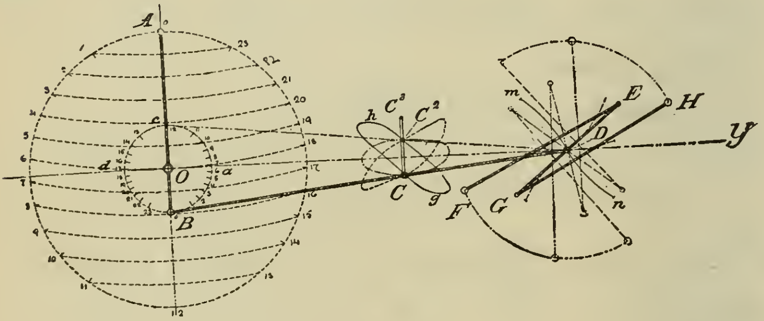
A NEW VALVE MOTION.

By Carl Angstrom, Worcester, Mass.

[Read before the American Society of Mechanical Engineers, November, 1883.]

This valve motion belongs to the same category as those of Brown, Marshall and Joy, and known by the name of "radial" valve motions.*

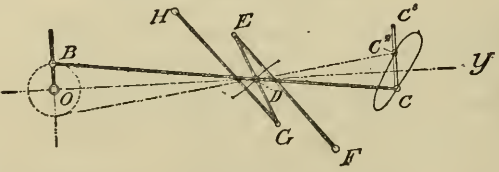
Fig. 1 *a*.



Ratio of Connecting rod to Crank = 5:1

In a radial valve motion, the motion is generally accomplished by an arm, two points of which move in different curves. One point moves in a closed curve, such as a circle or an ellipse, this motion being derived from an eccentric, crank or from the connecting-rod. The other point again moves either in an open or a closed curve, and this motion is accomplished either by levers or slides, or both combined.

Fig. 1 *b*.



In the valve motion to be described the difference from those previously mentioned consists chiefly in the mechanism for giving motion to the last mentioned point of the valve actuating arm.

The outlines of the valve motion are shown in Fig. 1 *a*, in which O is the centre of the main shaft, O A the crank, and O B the eccentric radius. The valve-rod C C^3 is attached to the arm B D at the point

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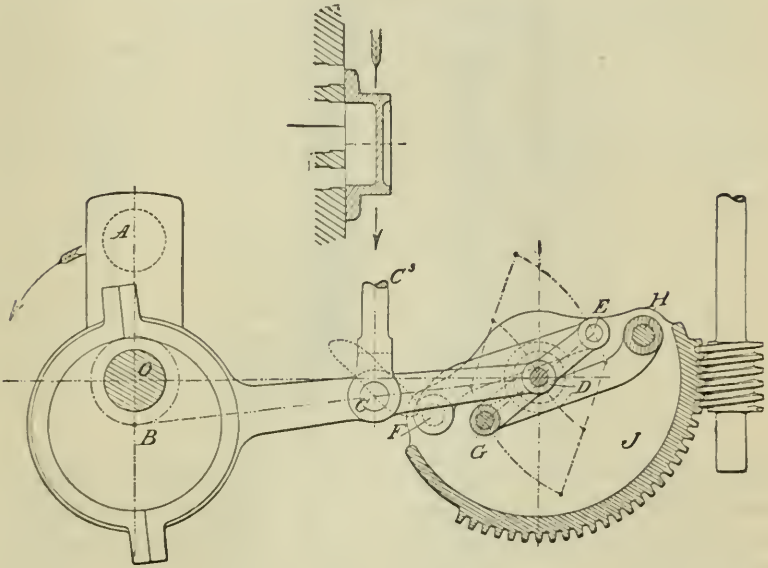
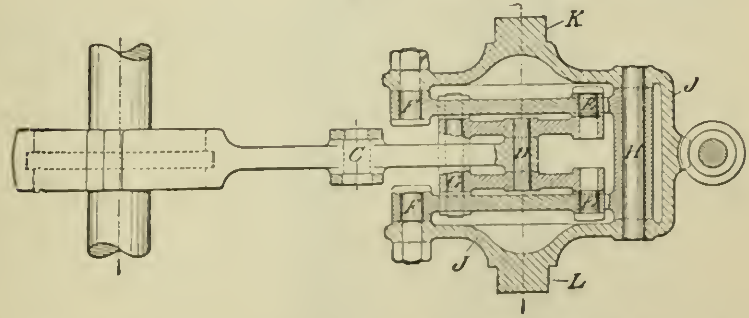
* "On Radial Valve Gears," by R. H. Graham. *The Engineer* (London), February 23, 1883.

FIG. 2.



C. The arm B D is connected at D by means of a cross piece E G to the two radial arms E F and G H. These radial arms are pivoted at E and H to a frame, J (see Figs. 2 and 3), this frame being free to turn on trunnions K and L, the center line of these trunnions being

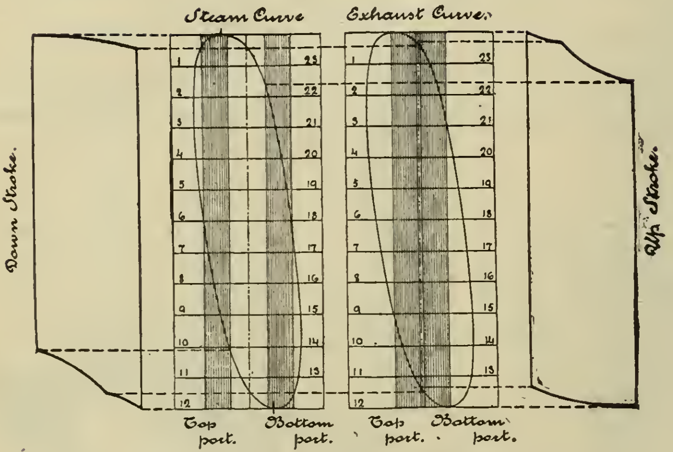
FIG. 3.



coincident with the point D on the rod B D at the end positions A and A^2 of the stroke A A^2 of the crank. The combination of the radial

FIG. 4.

Forward Motion.



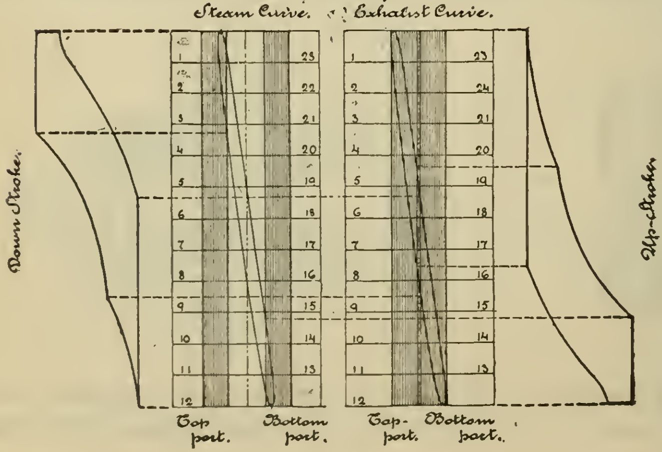
Ratio of Connecting rod to Crank = 5:1.

arms E F, G H and the cross piece E G with the arm B D makes the point D move in a reversed curve, *m* D *n*. The point B again moves in a circle, B *a c d*, and the point C, to which the valve-rod is connected, will thus have the combined movement C *g* C^2 *h* derived from the

FIG. 5.

Forward Motion.

¼ Cut-off.



circle and curve motions. The degree of expansion and the reversing of the motion is accomplished by changing the angularity of the reversed curve *m* D *n* with reference to the line O Y. This change in angularity is done by simply turning the frame J on the trunnions K and L. As shown in Fig. 1 *a*, all the different curves representing the travel of the valve-rod pin C will intersect at two common points C and C_2, each at equal distances from the center line O Y, the corresponding positions of the piston and crank being at the upper and lower end of the stroke. The valve is proportioned so as to give the desired lead at these two points, and this lead then remains constant at any degree of cut-off at either forward or back motion.

FIG. 6.

Backward Motion.

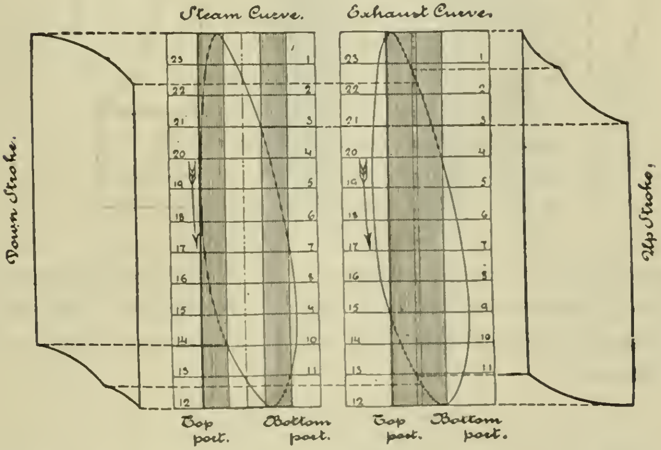
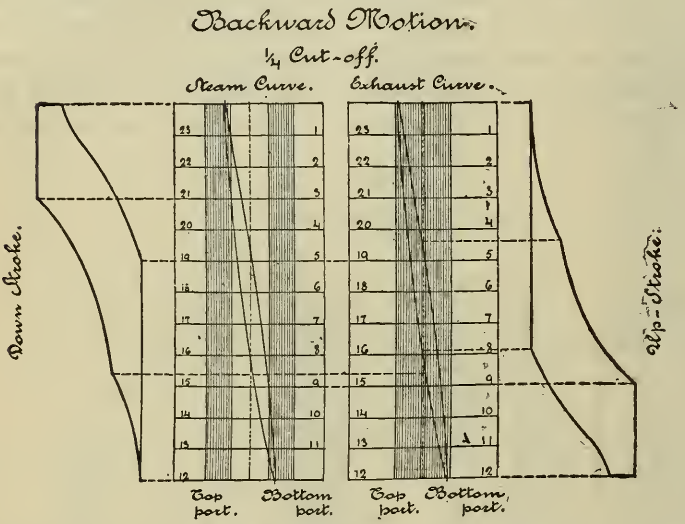


Fig. 1 *b* shows a modified arrangement of this same valve gear, the valve-rod C C^3 being connected to the end of the rod B C, instead of inside, as in Fig. 1 *a*.

Figs. 4, 5, 6 and 7 illustrate the motion curves for full gear and for quarter cut-off for both forward and back motions. On each side of the motion curves, as shown in the figures, are diagrams similar to indicator cards, showing the steam distribution for each end of the cylinder. These diagrams are simply intended to assist in locating the various points on the motion curves. The curves for forward motion, Figs. 4 and 5, indicate an exceedingly quick opening or steam admission, while the closing or cut-off is more like a common link motion. It is thought that this valve motion can be used with advantage on engines running chiefly in one direction. The pendulum links and

FIG. 7.



connections could then be proportioned so as to give a good steam distribution and equal cut-off at each end of the stroke. The cut-off could be changed automatically by allowing the governor to act on the movable frame J.

Sounds Produced by the Wind.—Eolian harps and telegraph wires furnish familiar examples of musical vibrations which are produced by the action of the wind. The statue of Memnon and the monument near Karnac, which was described by Jollois and Devillers, emit musical sounds which have been variously explained. In the Sinaitic range there is a cone of sandy rocks, called the Gebel-Nakus. When a traveller attempts in fine weather to scale this miniature peak, he hears a sound like that of distant bells. When there is no wind and the sand is damp with dew the sound is not heard. The phenomenon is attributed to the friction of the siliceous sand on the declivities of the cone. The atmospheric vibration which is thus started is supposed to be intensified by cavities, which serve as sounding boxes, or resonators.—*Chron. Industr.*, March 25, 1883. C.

A SIMPLE AND SENSITIVE THERMOSTAT FOR INCUBATION AND ARTIFICIAL DIGESTION EXPERIMENTS.

By N. A. Randolph, M. D.

Of the many devices employed to maintain a constant temperature in water-baths or air-chambers the great majority are either expensive, bulky or unresponsive to slight thermic changes. The instrument about to be described presents no claim to novelty, except in the method in which alcohol is employed to increase its sensitiveness, but it occupies very little space, and can be made by any one, at an expense so slight as to render it available to every student.

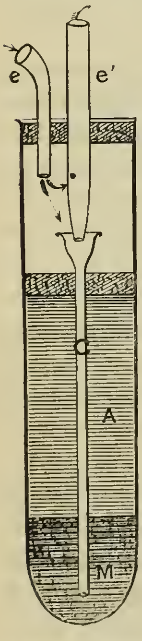
Take an ordinary 6 inch by 1 inch test-tube, and pour in sufficient distilled mercury to fill the bottom of the tube to a height of one and one quarter inch. Fill the tube to two inches above the level of the mercury with rectified alcohol; force down a tight-fitting flat rubber cork, having one central perforation, until its lower surface just touches the alcohol, care being taken that no air bubbles are included. Then introduce through the hole in the cork a narrow tube, flared funnel shape, nearly half an inch in width at its upper end. This tube should fit very closely to the cork, and its lower end should reach to within an eighth of an inch of the bottom of the test-tube. Another flat and closely fitting rubber cork should be provided, in which are two holes, one in the centre, the other to one side. In the central hole is introduced a tube, the lower end of which is somewhat drawn out, so as to easily enter the enlargement at the top of the first tube. On one side of the second central tube, and about three-fourths of an inch from its narrowed end, a minute hole should be filed or blown of a diameter just sufficient to permit the passage of enough gas to keep a flame alive; the second (lateral) hole in the upper cork is fitted with a plain short tube, which is connected with the gas supply, the top of the central tube being connected with the burner warming the water-bath or other vessel.

The completed apparatus is shown in section in the cut below, in which M represents the mercury, A the alcohol, C the funnel-tube projecting through the two liquids, *e* the gas admission tube, and *e′*

the gas exit tube provided with the small opening referred to, to keep the flame from being entirely extinguished.

The thermostat being placed in the same vessel with the material requiring a constant temperature, all the gas supplying the flame beneath the vessel is passed through the instrument and its volume modified as follows:

Upon any increase of temperature the alcohol can expand only downward, pushing the mercury up the lower central tube until it seals the lower end of the upper central tube, through which by far the major part of the gas (which enters by the lateral tube) escapes.



The flame being now reduced, any fall in temperature in the medium surrounding the thermostat and the material under observation will be followed by a descent of the mercury in the lower central tube, with a consequent unsealing of the main exit of the gas supplying the flame.

The instrument may be adjusted to maintain any temperature within certain limits by moving the upper central tube up or down, as the case requires. In the first adjustment a thermometer is necessary, but after the precise height to which the mercury rises at the required degree of heat is determined, the lower end of the upper central tube may be fixed at that point, and no further adjustment will be required for some time.

Should the minor gas exit (whose office is to permit the passage of just enough gas to preserve a mere point of flame) prove too large, the defect is easily remedied by pushing into the tube a small piece of paper, so bent as to accurately fit the interior of the tube, until the passage of gas through the minute hole is retarded to the proper degree.

A good glass-blower can make this instrument in one solid piece, in which case the adjustment (after the introduction of the alcohol) must be made by the addition or withdrawal through a capillary tube of minute globules of mercury.

In any case, the instrument must always be kept in an upright position.

Biological Laboratory of the University of Pennsylvania,
November 1, 1883.

Relations of Fluidity to Galvanic Conductivity.—Carl Stephen gives the following equation; $k = \frac{w K H}{w' \eta}$; in which K represents the conductivity of a water solution of the same temperature and percentage as an alcoholic solution with which it is compared; H and η, the internal frictions of the water and of the alcoholic fluid, for the same temperature; w and w', the percentages of water in the alcoholic solution and in a mixture of alcohol and water of minimum fluidity. He gives the following conclusions: 1. The frictional coefficient of many mixtures of water and alcohol, as well as the galvanic conductivity of diluted solutions of various salts, can be readily estimated. 2. The conductivity of diluted alcoholic solutions increases more slowly, when the amount of salt is increased, than that of water solutions. 3. The temperature coefficients of the conductivity of diluted solutions correspond very nearly to those of the fluidity of the solvent. 4. The conductivity of the alcohol-and-water solutions may be deduced from that of the corresponding water solutions, by a factor which depends only upon the solvent, and is the same for different salts. 5. If the proportion of alcohol is not greater than that of water the conductivity is very nearly proportional to the fluidity of the solvent.—*Ann. der Phys. und Chem.*, October 15, 1882. C.

Constitution of Comets.—No less than seven comets have been observed during the past year, one of which was photographed by Janssen in France, Common in England, and Draper in New York. Huggins states that carbon, hydrogen, and nitrogen are undoubtedly found in the substance of comets, and oxygen also is probably present. The chemical composition of twenty comets which have been studied appears to be essentially the same. There are often certain secondary modifications, which show that the predominant conditions are not rigorously uniform, and that they may vary from day to day in each comet. The temperature, the density, the amount of gaseous matter emitted by the nucleus, undergo continual variations. It is probable that the spectrum of hydrocarbon is complicated by traces of the spectra of compounds of oxygen and carbon. Meteorites are probably of the same nature as comets, and gases can be extracted from them in such quantities as to be exhibited before an audience. In 1867, Professor Odling, when lecturing upon the researches of Graham, lighted the lecture-room with gas that a meteorite had brought from the realms of space. The meteorite was chiefly iron, and contained nearly three times its volume of gas, of which 85 per cent. was hydrogen, 5 per cent. carbonic oxide, and 10 per cent. nitrogen. Professor A. W. Wright found in a stony meteorite, gases which occupied a volume two and a half times as great as that of the meteorite, or twenty times as great as that of the iron which was dispersed in its mass. The gases were the same, but in different proportions. The idea that the light of comets and the phenomena of their tails are produced by electricity appears to be spreading. Zöllner, especially, has endeavored to show that the known laws of electricity are altogether sufficient to explain cometary phenomena. It has been commonly supposed that the bright lines in cometary spectra indicate heated luminous gases. Professor Wright and Johnstone Stoney think that the decomposed vapor is opaque, as compared with the special rays which appear like bright lines, and that the brightness is due to the reflection of the sun's rays from the vapor. Stoney regards the phenomenon as one of phosphorescence.—*Ann. de Chim. et de Phys.*, November, 1882. C.

Recent Progress of Electrical Science.—During the last four years one hundred and twenty-five patents have been taken out in England for dynamo-electric machines, and one hundred and seventy for electric lamps. The great financial disturbance in France interrupted the extension of electric lighting, and du Moncel laments the comparative indifference of the French inventors. The question of economy is still a doubtful one, but the practical question of satisfactory electric illumination has been thoroughly solved. The complete success of electric lighting on shipboard would naturally lead us to look for its application to railroad trains, but although many experiments have been made in England, France, and Italy, the system has not yet been adopted upon any line. The transport of energy by electricity has been utilized in some establishments, but there are no indications of its general introduction.—*La Lumière Electrique*, January 26, 1883. C.

Dynamogen.—M. Pétry has devised the following process for manufacturing an explosive paper, which he calls dynamogen. He puts upon the fire an enamelled iron pot containing 150 grammes of pure water, in which he dissolves 17 grammes of yellow prussiate of potash, and when it boils he adds 17 grammes of charcoal, stirring the mixture well together. Allowing the whole to cool somewhat, he adds, successively, 35 grammes of potash, 70 grammes of chlorate of potash, and 10 grammes of starch triturated in 50 grammes of water. The whole is stirred, so as to constitute a very thin paste, which is spread with a brush over ordinary filtering paper. The paper is dried upon a moderately heated plate, and the other side is varnished in like manner. After three coats have been laid upon each side the paper is dried. It can be cut without danger and made into cartridges.—*Chron. Industr.*, January 1, 1883. C.

Invasion of England by a Subterranean Tunnel.—The opposition of the English Government to the construction of a tunnel under the English Channel has awakened great surprise. The French people can hardly believe that a great nation like England can allow itself to be guided by puerile fears. Some of their journals have reproduced an engraving, which was first published in 1803, and which shows that the idea of invading England by a tunnel had been formed at the very beginning of the century, at a time when Bonaparte had just visited the camp at Boulogne, and had monopolized all the vessels on which he could lay his hands, in order to carry out his famous project of a descent upon England. The engraving represents the channel as filled with ships-of-war and gunboats, the air with balloons freighted with soldiers, and large kites with gunners fastened to their tails, the fortresses on each side of the channel, and cavalry, infantry, and artillery marching through the tunnel. Although the engraving was probably intended as a burlesque, it seems no more absurd than the fears which threaten to prevent the execution of the tunnel, which was planned in 1875 and recommended by an Anglo-French commission in 1876.—*La Nature*, No. 497. C.

Protection against Rust.—Dr. Beckers has invented a preservative against rust, which is sold under the name of oil of caoutchouc, and which is said to have been introduced into general use by the German army. It is a varnish, prepared by mechanical means which have hitherto been kept secret, but which result in so intimate a mixture of the oil and caoutchouc that the latter preserves all its elasticity, and communicates it also to the oil. When rubbed by a flannel upon a metallic surface it dries slowly, forming a perfectly elastic, adhesive pellicle, which protects the metal from atmospheric influences.—*La Papeterie; Chron. Industr.*, No. 50. C.

Electric Omnibus.—The electrical storage company at Millwall, London, has constructed an electric omnibus, which moves with a velocity of six miles an hour. A number of accumulators, weighing 80 pounds each, and capable of driving the tramcar for seven hours, are placed under the seats and the current is communicated by insulated wires to a Siemens dynamo, which acts as motor. The electricity which is furnished by the accumulators, serves not only to drive the carriage but also to give it light.—*Lumière Electrique*, April 7, 1883. C.

Metallic Veins.—Dieulafait affirms that in a metallic vein there are always three constituents; the metallic substance, quartz, and sulphate of baryta. He has found, in many of the deep channels which are worn by glaciers, crystallized quartz, which must have been formed in the quaternary period, under conditions of pressure and temperature nearly identical with the present. He also finds, in examining 900 specimens of primordial rocks, that there is not one however small, which does not give appreciable quantities of sulphate of baryta, as well as of metals, diffused through the mass; he has thus recognized the presence of copper, lead zinc, manganese, and even vanadium, a metal which has been considered very rare. By observations in salt marshes and in the Caspian sea it has been found, that when fishes come into concentrated sea-water they die and fall to the bottom, where they decompose and produce sulphuretted-hydrogen which precipitates metals in the form of sulphurets; afterwards, the concentration still going on, the sulphate of lime is precipitated in its turn and covers the metalliferous layer, as in the Mansfield bed. Hence Dieulafait concludes that metalliferous layers, veins, pockets or ores, may be produced by mutual chemical actions, under present atmospheric conditions.—*Chron. Industr.*, March 25, 1883. C.

Transfer of Energy by Electricity.—In discussing Tresca's experiments at the Northern Railway station, the president of the Society of Civil Engineers remarked upon their great value. Even if a quarter of the original energy could be transmitted, there would be many cases in which a force could be transported to a distance, which it would be impossible to produce at the place where it is used. M. Chrétien, thought that the delivery would vary largely under varying conditions. He claimed personally, to have transmitted 60 per cent. in some cases, and even more.—*Chron. Industr.*, March 25, 1883. C.

CORRESPONDENCE.

Committee on Publication of the Journal of the Franklin Institute.

GENTLEMEN:—I have the honor to submit for publication the following new proposition on the attraction any solid body exerts at the level of a liquid mass surrounding it.

Prop. Let a liquid mass be in equilibrium around any solid body, whatever, the level of such liquid will be a surface of equal attraction.

In fact, the equilibrium being established, let us imagine an outer stratum of liquid of equal and very small thickness to become solid like a shell, without changing its density; and at different points of such shell let us drill equal holes and replace in them the same discs we have removed just as if they were pistons. It is evident that by the principle of equal transmission of pressure in hydraulics, and the condition of equilibrium, such discs must have all the same weight. Hence, the surface of level of the liquid must be a surface of equal attraction.

Corollary. If the disturbances caused by centrifugal force and luni-solar attraction on our planet be neglected, the level of the sea will be a surface of equal attraction. L. D'AURIA.

PHILADELPHIA, Nov. 14, 1883.

Book Notices.

FRENCH FOREST ORDINANCE OF 1669. Compiled and translated by John Croumbie Brown, LL.D. Edinburgh: Oliver & Boyd, 1883.

It appears, from an examination of this work, that the famous Forest Ordinance promulgated by Louis XIV, King of France and Navarre, and since known as the French Forest Ordinance of 1669, forms the basis of all existing laws relating to the subject of forestry. It is, therefore, of much historical interest, aside from scientific bearings, and it is somewhat surprising to learn from Professor Brown that the text of this ordinance appears for the first time in the English language in his work.

It contains much that is curious and interesting, and to those who are specially devoted to the subject of forest preservation and cultivation—which is rapidly becoming an important one in the United

States—it will doubtless be highly appreciated. The author is a devoted student of the science of forestry, and his present translation and compilation will prove a most desirable contribution to the bibliography of the subject in the English tongue. W.

THE BREWER, DISTILLER AND WINE MANUFACTURER. Edited by John Gardner, F.C.S. Illustrated. Philadelphia: P. Blakiston, Son & Co., 1883. 12mo, pp. 278.

The volume here noticed is represented to be the first of a series of "Technological Handbooks," prepared with a view of conveying in condensed form as much practical information as possible, so that those desirous of informing themselves concerning the practical details of any one of the technological arts may find therein everything that is essential. The design is a good one, and there is need of a series of the kind named, if edited by competent specialists.

The present work forms a very creditable beginning of the series. It is quite comprehensive and, so far as we have been able to examine it, accurate. It will be found useful for reference by the manufacturer, and particularly valuable by the novice wishing to familiarize himself with the principles and methods involved in manufacturing fermented and distilled liquors, and alcoholic compounds generally.

The publisher announces that this volume will be followed by one devoted to bleaching, dyeing, etc. W.

THE ELEMENTS OF CHEMISTRY, for the Use of Schools, Academies and Colleges. By Edwin J. Houston, A. M., etc. Philadelphia: Eldredge & Brother, 1883.

There is room for a well-digested, systematic, elementary work upon chemistry, elucidating plainly the views respecting the nature of chemical force, the facts respecting gaseous combinations by volume, the theoretical ideas of the quantivalence of the elements and its influence on molecular structure, the theory of substitution, and other facts and theories, the general appreciation and acceptance of which have revolutionized both the nomenclature and the methods of teaching the science.

This need the author has succeeded very well in filling, and the present work may be safely recommended to teachers of chemistry as perhaps more clearly and concisely presenting the most recent developments of the science than any other elementary text-book extant.

The author has been exceptionally successful as a maker of text-books, as the popularity of his several works on Physical Geography and Natural Philosophy attests, and for this work he is especially well qualified by the gift of a happy faculty of clear and concise expression, in addition to which, his long experience as an instructor has enabled him to thoroughly understand the requirements of both teachers and pupils.

The present volume is fully illustrated, neatly printed on good paper, and substantially bound. It will, doubtless, take its place with the other works of this author, as a favorite text-book. W.

MANUAL OF THE RAILROADS OF THE UNITED STATES FOR 1883, ETC., ETC. By Henry V. Poor. [16th Annual Number.] New York: H. V. & H. W. Poor, 70 Wall street. London: Effingham Wilson, Royal Exchange, 1883.

Poor's Manual of Railroads has come to be looked upon as a standard work of reference for information, statistical, historical and descriptive, respecting the railroads of the United States. For all having business or other relations required a knowledge of the mileage, stocks, bonds, cost, traffic, earnings, expenses, organization, etc., of the railroad companies of this country, the work is simply indispensable. The sixteen annual volumes which Mr. Poor has issued form an exceedingly valuable history of the rise, progress and present status of the railroad systems of the United States.

TWENTY YEARS WITH THE INDICATOR. By Thomas Pray, Jr., M.E., C.E. Boston: Boston Journal of Commerce Co., 128 Purchase street. 1883.

This work comprises 162 pages and 95 illustrations, and contains an account, in such form as to be intelligible to one unfamiliar with the subject, of the author's experience of twenty years in the use and application of the indicator in correcting and improving the economical efficiency of steam engines. It is illustrated by numerous diagrams, as mentioned above.

These diagrams are engraved to scale, and most of them have been taken from actual practice, produced just as they left the indicator, from marine and stationary engines.

The indicator diagrams, simple as they are to those who understand how to read them, are, unfortunately, a sealed book to only too many engineers.

This work, however, by its lessons, shows plainly the difference between good and bad diagrams as they are selected from the twenty years' practice of the author, with reference to the special business in hand, and any person who is operating with steam as a motive power may read it with profit. W. B. L.

Franklin Institute.

[*Proceedings of the Stated Meeting, held November* 21, 1883.]

HALL OF THE INSTITUTE, NOV. 21, 1883.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

There were present 92 members and 16 visitors.

The minutes of the previous meeting were read and approved. The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, November 14th, 13 persons had been elected to membership.

The Secretary, by instruction from the Committee on Science and the Arts, reported that the Committee had recommended the award of the Scott Legacy Medal and Premium to Messrs. Blodgett Brothers & Tirrell, of Boston, for their improvements in Electric Signal Clocks, and to Arnold Nacke, of Philadelphia, for his improvement in Screw Cutting Devices. He also reported that the same had been advertised for three months in the JOURNAL, and that he had received no objections thereto.

Mr. J. E. Mitchell, seconded by Hector Orr, moved that the recommendation of the Committee to award the Scott Legacy Medal and Premium to Blodgett Brothers & Tirrell, for their improvment in Electric Signal Clocks, be approved, and that the Secretary be directed to notify the Committee of Minor Trusts of the Board of City Trusts of the action of the Institute. Carried.

A similar motion, by the same movers, was made on behalf of Mr. Arnold Nacke, for his improvement in Screw Cutting Devices, which was also carried.

Mr. J. E. Mitchell then moved to suspend the usual order of business, in order to permit action to be taken respecting the recent death of Mr. Edwin Greble, of Philadelphia, for many years a member of the

Institute. The motion was carried. Mr. Mitchell thereupon made the following remarks:

"MR. PRESIDENT:—It becomes my painful duty to announce to the Institute the death of one of its oldest and most useful members—EDWIN GREBLE—who died October 23d, in the 78th year of his age.

"Mr. Greble was elected a member of the Institute in 1833, only nine years after its organization, and has been an honored member for over fifty years.

"From the time of his election, in 1833, up to 1864, Mr. Greble was one of the most active workers in the management of the Institute, having served on several important committees, and for nearly a quarter of a century, from 1841 to 1864, was an active member of the Board of Managers, and its chairman in 1848.

"Almost his only living colleague at this time is Mr. Frederick Fraley, who bears testimony to the great value of his services at this early period, and of his entire devotion to the best interests of the Institute.

"Mr. Greble was always a loyal citizen of Philadelphia, his native city, his son, Lieutenant Greble, being one of the first to fall in the defence of the Union.

"He was honored by a seat in our City Councils in 1862, and was chairman of the committee to disburse the money provided to aid in furnishing soldiers during the late war, and many thousands of dollars passed through his hands. He was elected a Trustee of the Pennsylvania Museum and School of Industrial Art, and took a deep interest in everything calculated to improve the taste and elevate the condition of the working people, many beautiful monuments and other works in marble and granite remaining as the result of his taste. I therefore beg leave to offer the following:

"*Resolved*, That in the death of Edwin Greble, which occurred on 23d of October last, in the 78th year of his age, the Franklin Institute has lost one of its earliest and most useful members, one who by his actions, aid and counsel in the early days of the Institute did much to lay the foundations on which rest its present high position of usefulness, and who secured the respect of his colleagues in after years by his hearty co-operation in carrying forward its work.

"*Resolved*, That his fellow-members hereby tender to his family their respectful and heartfelt sympathy."

The resolutions were adopted without dissenting voice.

The Secretary's report embraced remarks upon the amendments to the British Patent Law, which go into effect on January 1, 1884; the project for a second ship canal across the Isthmus of Suez; the general adoption throughout the United States of the New Standard of time; a description of an improvement in Saddles by Mr. P. McFadden, of Philadelphia; of certain improvements in the construction of Organs by Prof. Gally, of Boston, which were described by Mr. William Blasius; of an automatic device invented by P. E. Jay, of New York, for preventing the freezing of water pipes, consisting of a valve in the water pipe placed above the point at which there may be danger of freezing, and so adjusted that before the weather becomes cold enough to freeze the water in the pipes, the valve is automatically opened, a flow of water is established through the pipe, and the same thus protected; and of an automatic cut-out, devised by Messrs. Pinkham & Seal, of Philadelphia, and designed to preserve an open circuit battery from injury when accidentally close circuited for any length of time, and which will again make proper connections when the ground has been removed.

A strong magnet, of low resistance, controls an armature, which in turn operates an insulated cylinder by means of a connecting rod. Attached to the upper end of this cylinder is the segment of a cogwheel, which engages in a smaller one bearing a fan, the object of which is to offer sufficient resistance to the armature to cause it to move slowly.

The outer surface of this same cylinder, which is about $\frac{5}{8}$ inch in diameter, and about 1 inch long, is faced with platinum, against which three fingers, secured to a post of rubber or other insulating substance, come in contact. These fingers are made of a good conductor, possessed of more or less elasticity. The first finger plays upon the platinum surface above described the entire limit of its partial revolution, caused by the action of the armature. The second finger plays upon the platinum until the armature is drawn nearly up to the magnet heads, when it becomes insulated by a piece of rubber passing under it.

The third finger is the reverse of the second, being insulated from the cylinder until just before the second finger becomes disconnected, when it comes into contact with the platinum surface. No. 1 finger is connected with one wire of the magnet, the other wire being attached to a binding post in the instrument.

Fingers Nos. 2 and 3 connect with two more binding posts. A weight is secured to the cylinder in such position that when the magnet ceases to be energized the armature is carried back to its normal position.

The instrument is attached as follows: The magnet is looped into the ground wire of the battery by means of two of the binding posts. This disposes of fingers 1 and 2, which are always in contact on the platinum surface when the magnet is not energized. The other binding post is attached by wire to the same pole of a gravity battery which corresponds to the ground wire of the open circuit battery. The other pole is attached to same wire of the opposite pole of open circuit battery. This disposes of No. 3 finger. The action of the instrument is now very simple. Any vibratory connection, such as ringing a bell or lighting an automatic gas burner has no effect whatever upon the instrument. A single contact, such as is caused when ringing a stroke or tap bell or lighting a burner by the wire spark (so called), produces a slight impulse in the instrument; but should the contact be sustained for one-fourth of a minute, the energized magnet attracts the armature which revolves the insulated platinum surface, causing a change of connections. When at rest, fingers 1 and 2 are in contact. When energized, fingers 1 and 3 are in contact. No. 2, which connects with open circuit battery, has now become insulated, and No. 3 which connects with closed circuit battery has come into contact with No. 1, or ground wire. In this instrument the ground is not removed, but the circuit is simply changed from a battery which will be destroyed if grounded a sufficient length of time, to a battery whose nature is the reverse, and would therefore carry the ground without destruction so long as it has material to work upon. To preserve the closed circuit battery in a normal condition while not in use, it is close circuited through a coil of very high resistance which allows just enough current to pass through the battery to retain its strength.

Now, should the ground be removed by accident or otherwise, the magnet loses its energy and the armature is carried back to its normal position by the weight on the cylinder. The instrument is actuated upon by the open circuit battery up to a certain point when the closed circuit battery is thrown in and retains the armature at that point until the ground is removed, thus opening the circuit of the destructible battery.

The instrument is enclosed in a neat box about the size of a transmitter box, and has a glass front exposing to view a needle which points to the words "grounded" and "clear" according as the instrument is so operated upon. The box is locked to prevent tampering or mischief and the binding posts are secured to the upper end of the base which projects somewhat beyond the box itself.

Professor Edwin J. Houston being called upon by the Secretary to explain the invention of Mr. Patrick B. Delany, of the Synchronous Multiplex Telegraph System, remarked:

"It gives me great pleasure, Mr. President and gentlemen of the Institute, to call your attention to what I cannot but regard as the most wonderful electrical invention of the present time. I refer to the system of Synchronous Multiplex Telegraphic communication mainly the invention of Mr. Patrick B. Delany.

"You will the more readily appreciate the great value of this invention when I tell you that the only system of quadruplex telegraphy, by means of which no more than four messages can be simultaneously transmitted on one and the same wire, has hitherto been owned and operated solely by the Western Union Telegraph Company, and is justly regarded by that company as its most valuable invention. What then must be the value of Mr. Delany's invention, by means of which no less than seventy-two messages can be simultaneously transmitted on the same wire.

It will be almost impossible for me to give you a full description of this remarkable invention without the aid of drawings and apparatus, but I will do my best, leaving minor details to a paper which I will shortly publish in the JOURNAL of the Institute.

"The Synchronous Multiplex System differs essentially from the present quadruplex system, which, as you well know, is based on the balancing of resistances, whereby the transmitting operator's instrument is unaffected by the messages transmitted, but is ready for the reception of signals from the other end of the line.

"Mr. Delany's system, however, is based on the synchronous rotation of two discs, one at each end of the line, by means of which a single wire, constituting the line, is brought simultaneously into connection with corresponding operating instruments at each end of the line, and transferred from one set of instruments to another so rapidly that the operator transmitting or receiving does not realize that the line has been disconnected from one instrument and given to another, since each operator always has the line at his disposal, even at the highest rate of manipulation.

"It will therefore be understood that the synchorous system is based on the following simple fact; viz., that the time during which any telegraphic operator is actually using the line bears an exceedingly small ratio to the time that the line is out of use; and that in this system each operator follows the preceding operator, and uses the line only when it is not required by others. Although we speak of say seventy-two messages simultaneously transmitted on the same wire, yet, in point of fact, only one operator is using the line at any given time. The effect, however, is practically the same as if it were simultaneously used by all the seventy-two operators, since, if a single wire, connecting, say New York and Philadelphia, had seventy-two branches running from the terminus at Philadelphia, to seventy-two distinct operators in Philadelphia, and seventy-two branches running from the New York terminus to seventy-two distinct operators in New York, any seventy-two of these operators could, at any time, have the line at their disposal to the same extent as if it were a private line, entirely irrespective of whether any or all of the other operators were using it, since no two of them are given the line at exactly the same time.

"The practical success of this system is dependent on the ability to maintain perfect synchronism between the rotating discs at each end of the line. By the application of a beautiful system of perfectly automatic regulations the inventor has succeeded in obtaining this so thoroughly that the two discs can be maintained in continuous motion for days without varying from one another by as much as the six hundredth part of a second. This he effects by a series of electrical impulses sent over the same wire that connects the distant stations, at such times only that one instrument is slightly in advance of the other. Should the line connecting the two stations be accidentally broken, the synchronism between the two instruments would of course be lost, but since the control is entirely automatic, they would place themselves in synchronism with one another as soon as the line was connected.

"Although the mechanism requisite to produce these results is necessarily somewhat complicated, yet the extent of the complexities is by no means as great as might be believed necessary. Indeed, much less skill is required to keep the line in running order, than is requisite with the ordinary quadruplex system, for in the quadruplex system a change in the electrical condition of the line equivalent to a lengthening of the circuit for say ten miles, will throw the apparatus out of adjustment and stop all communication, while in the multiplex, as I myself have seen, an instantaneous change in the resistance of the line equal to five hundred miles, may be made without practically affecting the synchronous movement of the distributers, or interrupting the various circuits.

"A marked advantage of the synchronous system of telegraphy, over those now in use, is in the absolute secrecy. No tapping of a synchronous line can by any possibility disclose the nature of the intelligence being transmitted, since the line at the point tapped would then give not only all the messages it was then transmitting, but also the separate makes and breaks caused by the successive transference of the line to each of the operators connected therewith.

"In order to prevent the breaks caused by the successive transferrence of the line to the different operators from affecting the instruments at the other end, a very beautiful use is made of the well-known polarized relay, by means of which the operators' instruments respond not to changes in the continuity of the circuit, but to changes in the polarity of the sending instruments that are placed in the circuit of a split battery.

"This invention is due to Mr. E. A. Calahan, the inventor of the stock exchange printing telegraph, who has been associated with Mr. Delany in his inventions."

The report of the Joint Committee on the reading of Papers was then called up as the special business of the evening. After some discussion of the same, Mr. J. M. Eldridge moved the addition, at the close of resolution authorizing the Secretary to provide a signal bell, etc., of the words, "for a certain number of minutes." The same was approved.

Prof. E. J. Houston, seconded by Mr. Washington Jones, moved that so much of the report of the Committee as related to the alterations of the by-laws be indefinitely postponed, and that the remainder of the report be approved and adopted. Carried.

The report of the Special Committee on the "Examination of Steam Engineers," presented majority and minority reports. After much debate thereon, it was finally decided, on motion of Mr. J. W. Nystrom, to recommit the reports to the Committee, and to increase the number of its members from five to seven. The President appointed as additional members, Messrs. William A. Ingham and William Helme.

The meeting was thereupon adjourned.

Wm. H. Wahl, *Secretary.*

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